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42
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THE HOME STUDY COURSE IN ELECTRONICS AND COMPUTERS

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U.K. Technical Consultant
Dr. Robert King, Reader in Communications Engineering, Imperial College of Science and Technology, London.

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INDEX

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Editor:
Amanda Kirk

Technical Editor:
Keith Brindley

Art Editor:
Alistair Carlisle

Sub Editor:
Nicholas Bellenberg

Copy Consultant:
Chris Wallace (Creative Technical Services)

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11

COMMUNICATIONS

Cellular radio

What is cellular radio?

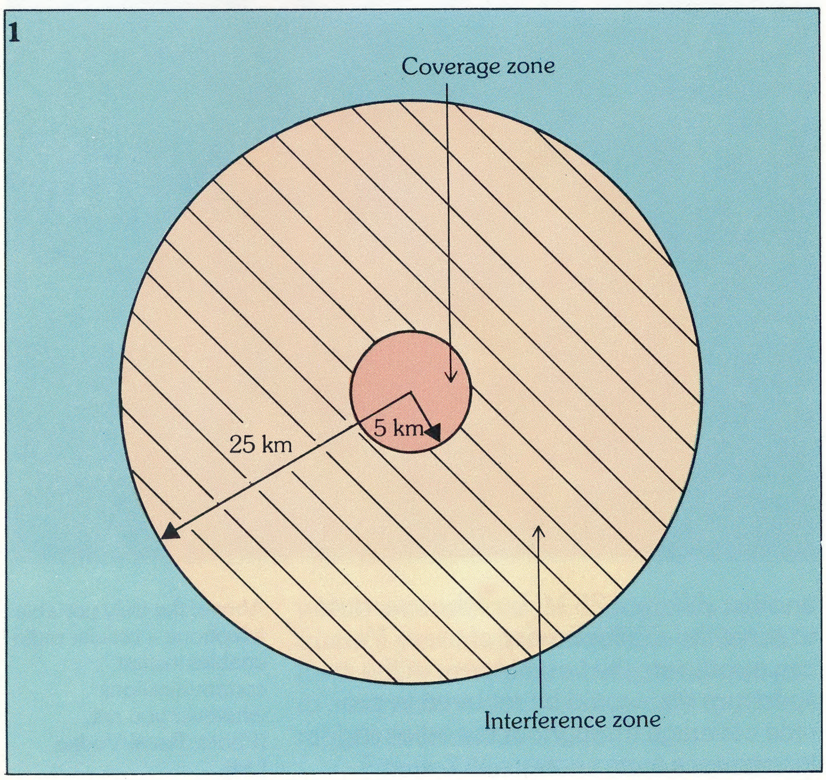
Conventional land based mobile radio services, especially those in densely populated areas, have suffered from radio channel congestion for a number of years, frustrating users and industry alike. In response to this, the Government, recognising the importance of mobile communications, released certain radio frequencies for land mobile radio use.

However, research has shown that even more frequency capacity will be required to meet the growing demand for mobile radio telecommunications. So, in 1982, 30 MHz of radio frequency spectrum in the 900 MHz band was allocated for a new mobile radio system – **cellular radio**.

Cellular radio is a mobile telecommunications system enabling a substantial increase in the number of mobile radio users. Densely populated areas, such as London, will be divided into **cells** as small as one square mile; while cells in rural areas may cover twenty square miles.

A low power transmitter with a set of radio frequencies controlled by a computer with switching capability is allocated to each cell. Adjacent cells have different frequencies to avoid interference, but cells sufficiently far apart are *able to use the same frequency*. It is this efficient re-use of frequencies which enables a far greater number of subscribers than would otherwise be possible.

1. Maximum utilisation of frequencies is obtained by reducing the size of the coverage zone. These frequencies can then be re-used outside the interference zone.



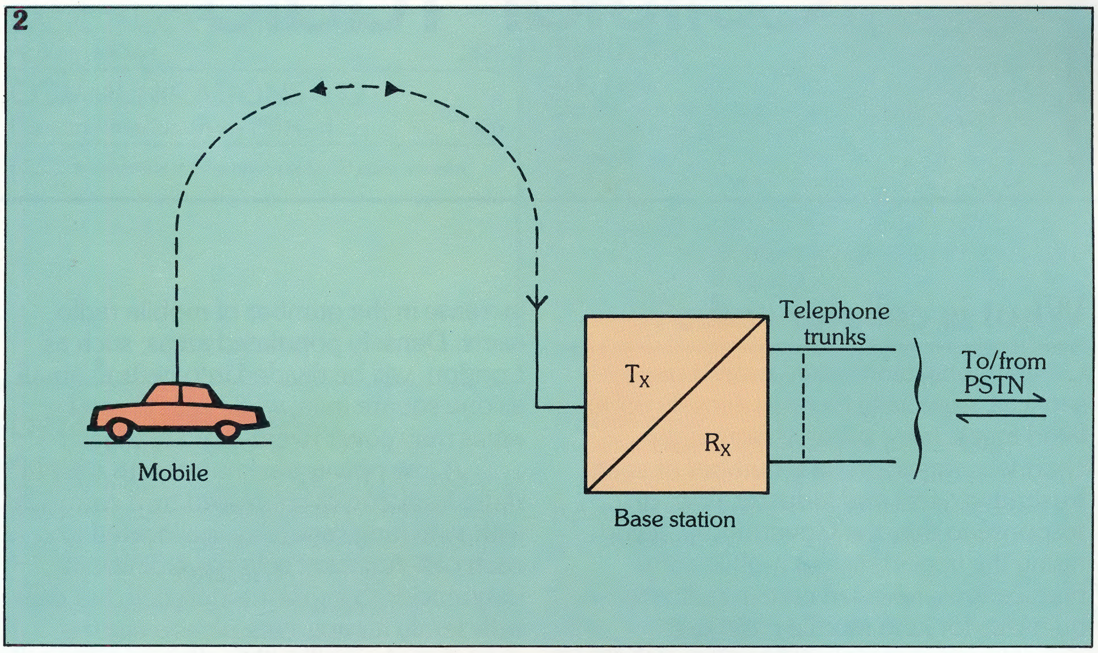
Radio spectrum allocation

We'll first consider the radio spectrum allocation and the basic radio frequency requirements of any mobile radiophone. As with a conventional telephone, a mobile radiophone user, talking and listening via the handset at the same time, requires a **duplex channel**. This means two different radio frequencies are used for the duration of the call – one to broadcast and one to receive. However, radio waves propagate and interfere with other systems using the same frequency up to a distance of at least 25 km (see *figure 1*). This means that these radio frequencies cannot be re-used within 25 km from the base station transmitter – but they *can* be used outside the interference zone.

The key to the cellular radio concept is the reduction in size of the coverage zone. This means that there are fewer users in each area, who therefore need fewer channels. This leads to the maximum utilisation of frequencies and the most efficient use of the available bandwidth.

Conventional mobile radio systems

A mobile radio telephone provides the user with all the features and capabilities of an ordinary telephone, except that it does not



2. The central feature of a mobile radiophone system is the base station. This is a powerful, multichannel transmitter/receiver connected to the PSTN via a network switch.

have wires and can be used anywhere within a reasonably large area. This should not be confused with the cordless telephone which can only be used within a short distance from its base unit.

Figure 2 illustrates the basic principle behind mobile radiophone systems. A powerful multichannel transmitter/receiver, known as a **base station**, is connected to the public switched telephone network (PSTN) by a number of telephone trunks. A fixed telephone subscriber can thus communicate with the mobile by dialling the base station. An aerial is usually mounted on a high building, or hill, to achieve the maximum possible radio penetration.

If, say, a single base station serves a city with an area of 100 square kilometres, and has 50 radiophones per square kilometre, it can be estimated that, in the busy part of the day, around 500 duplex radio channels would be needed to provide an acceptable grade of service for the 5000 users.

These channels require interconnection to 500 lines on the PSTN. These can be physically installed without great difficulty, however, the channels would also require 1000 different radio frequencies which are normally spaced 25 kHz apart at UHF frequencies. This is equivalent to 25 MHz of the frequency spectrum.

An adjacent area would require another different 25 MHz of the spectrum to serve the same number of users. You can appreciate the vast amount of the spectrum that would be required to provide coverage throughout the adjoining interference zone areas.

Above: the truly portable telephone – cellular radio enables instant communications wherever you are. (Photo: Racal-Vodac Ltd).

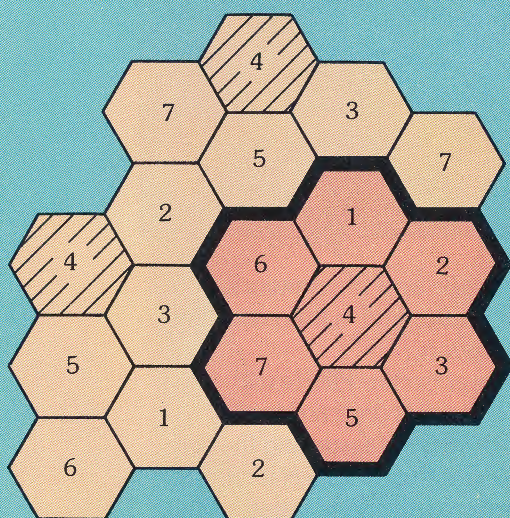
Cellular radio networks

In the cellular system, instead of one large high power base station covering a wide area, that same area is divided into a large number of small areas or cells. The basis of the cellular system rests on making each network's radio link as short as possible. Each cell therefore has a small, relatively low power base transmitter/receiver linked to an aerial system. The base station has an adequate range to cover the cell with only a small overlap around the boundaries.

Cells, although roughly circular in their area of coverage, are usually drawn as hexagons — this lends itself readily to the generation of uniform cell **clusters** which are necessary to formulate a frequency plan from the available channels. Each cell is served by a base station wired to a network which switches calls to a mobile as it moves about.

3. A seven cell cluster. Each cell operates with a different frequency set, but the pattern is repeated in adjacent clusters. Co-channel interference is kept within acceptable limits by ensuring that each cell is at least 5 times its radius from another cell using the same channel frequency set.

3



Typical radio telephone cells

Each hexagon is a cell

A cluster is embedded within the heavy lines

Each number denotes a different frequency set

Figure 3 illustrates a cluster consisting of seven cells. Each cell receives a seventh of the total available radio frequency spectrum allocated to the cluster, and contains, on average, one seventh of the total number of subscribers. The seven cell cluster is the most efficient and flexible structure, allowing the use of a coherent frequency plan, which is maintained even when cells of varying sizes are adjacent in the same system.

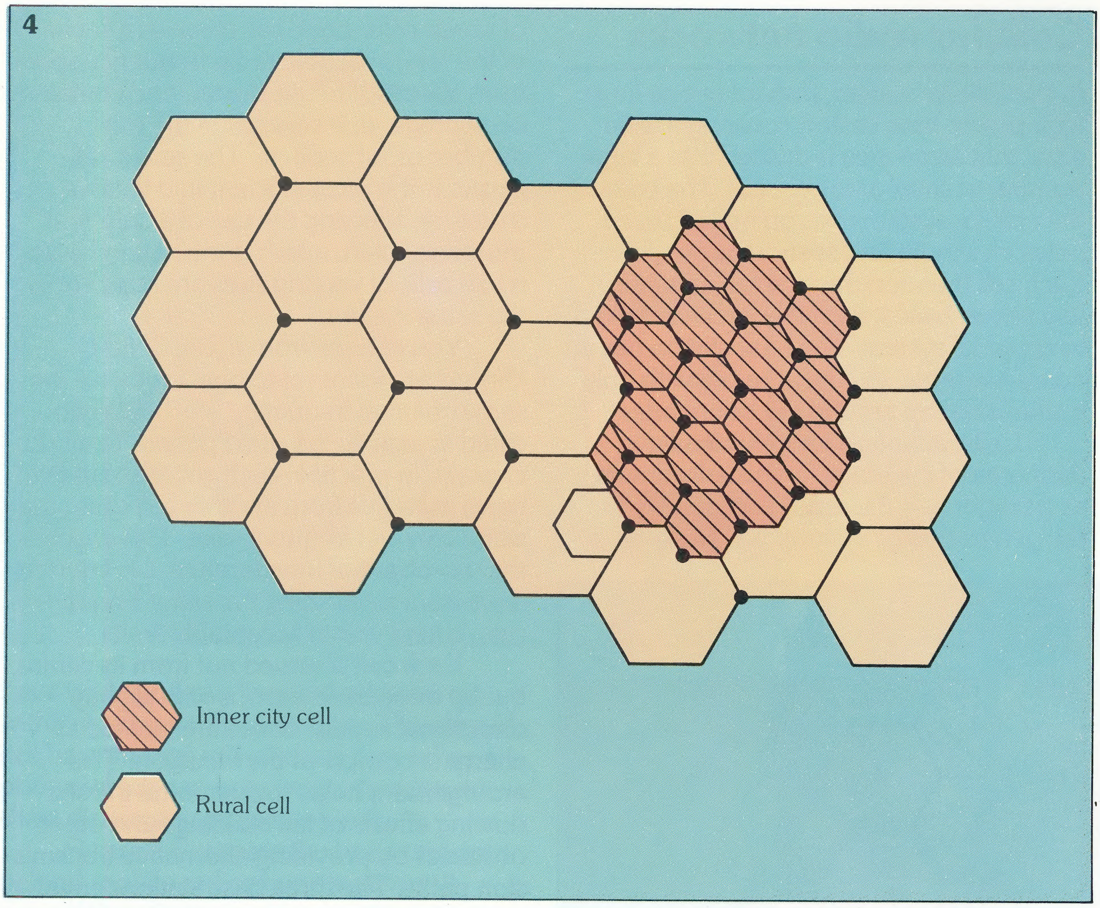
You can see from *figure 3*, that clusters are identical to one another – the same channel frequency sets being allocated in exactly the same pattern to all clusters. In practice, each cell is about five times its radius from another cell using the same channel frequency set. This ensures that **co-channel interference**, i.e. interference from a cell using the same frequencies, is kept within acceptable limits.

Each cell is served not from its centre, but by three base stations with slightly directional aerials. These are located at alternate corners of the hexagon. This arrangement helps to overcome the shadowing effects of tall buildings and other obstacles by providing alternative transmission paths. The three base stations covering each cell are connected by land lines to a **network switch** which is, in turn, linked to other network switches and to the PSTN.

Cell size is not fixed throughout the country and is related to the number of mobiles in a particular area. This means that the average number of users within each cell can be matched to the number of channels available. *Figure 4* illustrates a possible set up where city and rural cells are considerably different. The small dots in the diagram indicate the positions of the base stations at alternate corners.

Network switch

Each network switch handles a group of individual cells under the control of a computer. The computer automatically reassigns the equipment of any user who moves into another cell to new frequency channels, in a process known as **hand-off**. A schematic diagram is shown in *figure 5*. The network switch is also responsible for routing all calls: whether cell to cell; between two users in the same cell; or from



4. Cells can be of different sizes according to the number of users – these can then be matched to the number of channels available.

the PSTN to a cellular radio user and vice versa.

The complete system comprises a number of these network switches which keep track of all cellular radio subscribers on the move (so that they can be called quickly when they are dialled), and also look after time-keeping and the maintenance of all billing data.

System operation

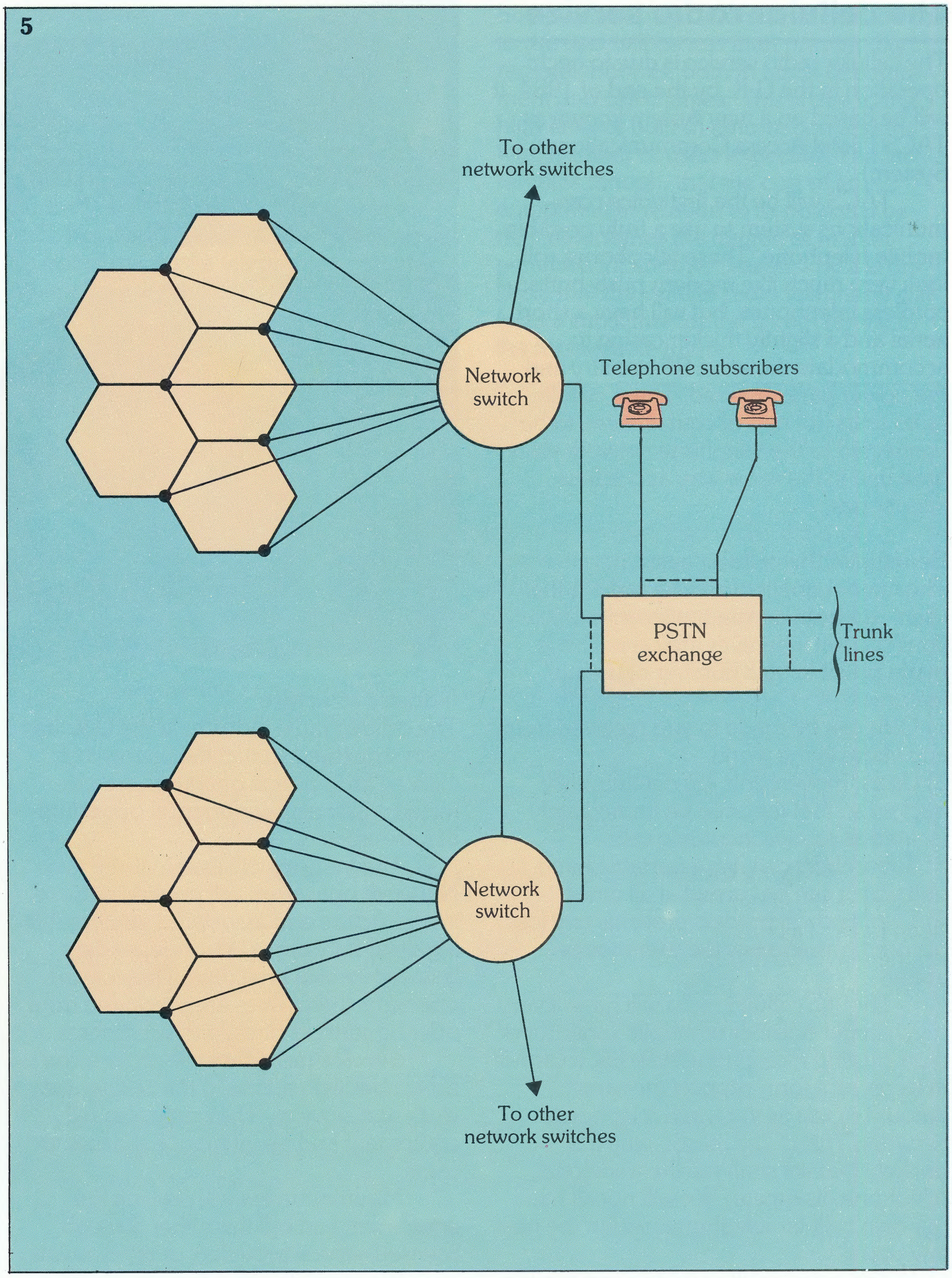
Each cell has a few **control channels** reserved for data communications between the base station and mobiles; these channels are not used for speech. If a mobile user wants to place a call, then the cellular radio equipment finds a free control channel and broadcasts a request for a communications channel. The base station continuously scans the control channels, and when it picks up a request, the network switch decides on the cell and the channel set that the mobile must use. If this channel set is available, it is allocated to the mobile which is then instructed to use it. This channel is used to exchange data between the mobile and the network during the call set up, and is then used for normal conversation.

If a fixed user on the PSTN wants to call a mobile, the call is directed to the nearest network switch (assuming the network knows where the mobile is located). The base stations controlled by this switch use spare control channels to identify the mobile. Mobiles continuously monitor the control channels when they are switched on but not in use. When it identifies its address, the mobile unit selects a free control channel and transmits an answer message to the base station to indicate its location. The base station informs the network switch, which then takes control, allocating the mobile an appropriate channel for the cell it is in and making it ring – all without the user's control or knowledge.

Hand-off

Base stations continuously monitor all calls in progress, and if the quality of communication falls below a certain standard, the **network switch control centre** is

5. Network switches handle all routing of calls. They keep track of all cellular radio subscribers and automatically reassign channel frequencies when a subscriber crosses into a neighbouring cell.



automatically alerted. This centre then monitors the signal strength at adjacent base stations, imperceptibly retunes the radio to a new channel and transfers the call to the appropriate base station. Communications are maintained throughout the hand-off process.

Hand-off is so fast that the user does not realise that the call has been switched over. The switching continues in a similar manner as the user crosses into further cells during the conversation. Careful planning and aerial siting ensure that communications between the user and the cell base station are highly reliable, with no radio black spots to interrupt conversation.

The cellular radio service

The cellular radio service is due to begin operation in the U.K. by the end of 1984. It will be based on a new system known as TACS (Total Access Communications System).

TACS will be the first voice communications system to use a truly portable mobile telephone. These telephones will look very much like modern push-button cordless telephones, but will have a short aerial and a slightly thicker casing to accommodate the extra RF circuitry and the power pack required. These cellular radio units will not, of course, need to be connected to the telephone network via a base unit in the same way as cordless telephones.

Benefits of the cellular system

The major benefit of cellular radio is that users can be in constant telecommunications contact wherever they are. This is made possible by a number of unique features:

1) Calls can be made to and received from anywhere in the world.
2) Users' movements are continuously tracked so that they can be immediately located to receive incoming calls.
3) Subscribers can use a portable hand unit which can be carried at all times.
4) The hand-off process prevents any loss of communication as the user moves about.

Though cellular radio will have a very much larger number of mobile subscribers than existing radiophone systems, it cannot in its present form support the same amount of use as the wired telephone network. This is one reason why it is unlikely that we shall see the traditional telephone disappear. We will not all have our own cellular telephones within the next few years!

The system will provide considerable benefits for users: **automatic call forwarding** (the facility for a call to be forwarded to another number when the dialled number is engaged or unanswered); **automatic re-dialling**; **audio teleconferencing**; **delayed calls**; and data communication facilities are all examples of the planned features.

Above: the cellular mobile telephone can also be mounted in a vehicle.
(Photo: Cellnet).

Industry structure

The cellular radio industry in the U.K. has been structured so that the interests of existing radiophone operators are protected whilst new commercial opportunities are created.

The industry will exist in three tiers. **Network operators** will provide network infrastructure and associated services (billing data, for example) to independent licensed service providers. The network operators themselves are precluded from offering services directly to subscribers.

Service providers will provide the subscriber with access to the cellular network and services. They may also sell equipment and maintenance services to users.

Manufacturers will provide the equipment and sell this either through licensed service providers or retail outlets.

It is estimated that there could be as many as 500,000 more mobile radio subscribers by 1990, thereby creating enormous commercial opportunities for existing and potential manufacturers and service providers.

All user equipment will need to be approved before it can be used over the cellular radio network.

Conclusions
The cellular mobile telephone has stimulated much interest, being in principle the first carry anywhere pocket telephone. For the first time, business people will be able to make and receive important telephone calls in their cars, in their gardens or even on the golf course. Similarly, people 'on call', like doctors and engineers, will never be out of reach of a telephone no matter where they are.

Cellular mobile telephones, involve considerable component miniaturisation, however, manufacturers claim that the cost to the user will be less than present day radiotelephones, both in terms of equipment and call charges. This is due to the high level of built-in automation and the high number of users expected. The fact remains though, that the cost of any equipment in relation to its potential benefit determines the degree of market penetration; another reason why it is unlikely that the cellular radio telephone will form a substitute for the wired 'phone in the foreseeable future.

Glossary

cell	in the cellular radio system, the country is divided into cells, each of which contains a low power radio transmitter. The size of each cell depends on the number of users within it. This system means that a small number of operating frequencies can be re-used up and down the country
cellular radio	new mobile communications system that allows the present number of mobile users to be increased
cluster	a collection of seven cells. Each cell within a cluster has a seventh of the available radio frequencies allocated to it. The seven cell cluster provides the most flexible and efficient structure
communication channel	radio channel along which voice communication is broadcast
control channel	radio channel along which the base station and the mobile unit communicate – not used for speech
hand-off	process by which a cellular radio user, crossing the boundaries of a cell or experiencing a bad signal, is transferred to a new radio channel, without any interruption of communications
network switch	computer system which allocates radio channels to the mobile units. Also handles the switching and tracking operations needed, and connects the system to the telephone network

COMPUTERS & SOCIETY 11

Electronic publishing

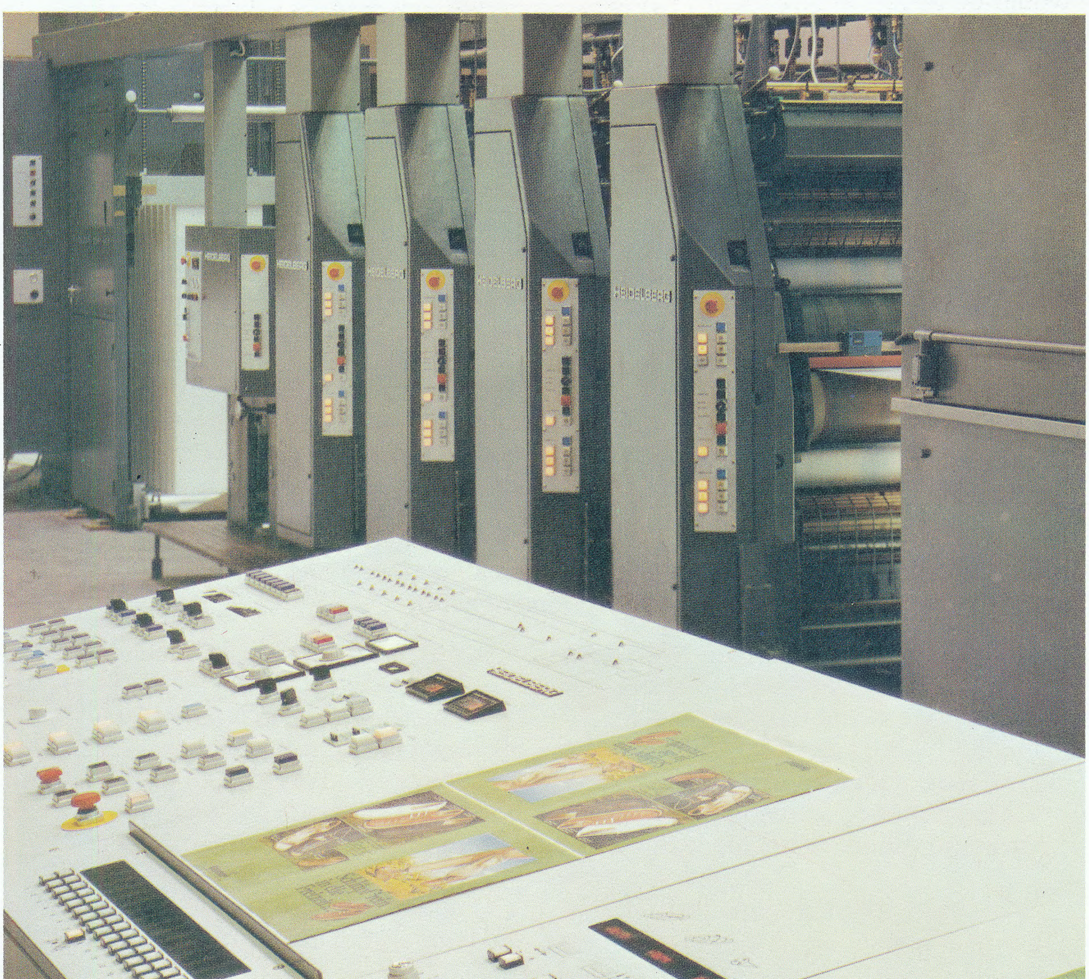
New technology and the news media

There is no office quite as exciting and fast moving as the newsroom of a paper on press day. The news floods in from reporters in the field, the 'phone rings, stories are written and rewritten, and practically before the ink is dry, issues are stacked in vans and whisked onto the news-stands.

Probably the most extraordinary fact about the majority of Britain's newspapers and magazines is that, until recently, they were produced in almost exactly the same way as the first papers at the turn of this century (in fact, some still are!).

Now, however, the publishing and broadcasting industries are on the edge of a second industrial revolution: the use of computers. This should not seem surprising to us, though, being as they are involved in the mass production, distribution and, to some extent, management of information. Because of this, these industries have found themselves amongst the first to be directly affected by the new technology.

Although some of the more obvious



Left: computer controlled printing systems are revolutionising the printing industry. This Heidelberg CPC 1 automatically records and resets 'ink profiles' for each job and, when connected to a central measuring console, it allows computer controlled monitoring of quality. (Photo: Heidelberg).

advantages of using computers in the publishing business lie in the ancillary areas of subscriptions management, advertising sales and accounts, it is the editorial office where the benefits of the new technologies will have their most revolutionary effects.

The essence of electronic publishing is the replacement of the traditional methods of typing and printing, and information storage and distribution on paper by the equivalent operations carried out by electronic means.

The introduction of such electronic methods, however, has been slow. This is due in part to the huge cost of transferring manually based systems onto automated systems and the lengthy lead times necessary to produce a reliable system suited to individual company needs.

Another problem is the vast array of different hardware and software available, much of which is incompatible. This presents a very confusing picture to the would-be buyer who frequently needs to commission a specialist report for advice.

Finally, and probably most important, is the reluctance of the workforce to train on new equipment if they feel that it will result in lost jobs.

Having said that, some companies have begun trials. Business Press International, for example, the world's largest publisher of trade and technical magazines, has given each journalist on *Crops Weekly* an ICL 16-bit microcomputer. Both union and management have co-operated and this pilot project is designed to measure if computers can increase efficiency.

Competition, of course, is a major factor in newspaper and magazine publishing. Getting the product onto the bookstalls at the right time and at a competitive price is the all important objective. Present day technology can play a vital role in achieving that target.

Word management

Word management refers to the electronic capture, storage and manipulation of text. It is the first stage in the electronic publishing process.

The most versatile and important tool for handling text is the word processor. (For a detailed look at the functions and operation of a word processor, see *Computers & Society 3*.) From a journalist's point of view, word processors simplify a writer's work in a number of ways – they cut out repetitive typing and enable extensive editing of text with the minimum of keystrokes. Production gains of 200-300% are possible when operators perform minimal keying in the revision of previously stored material.

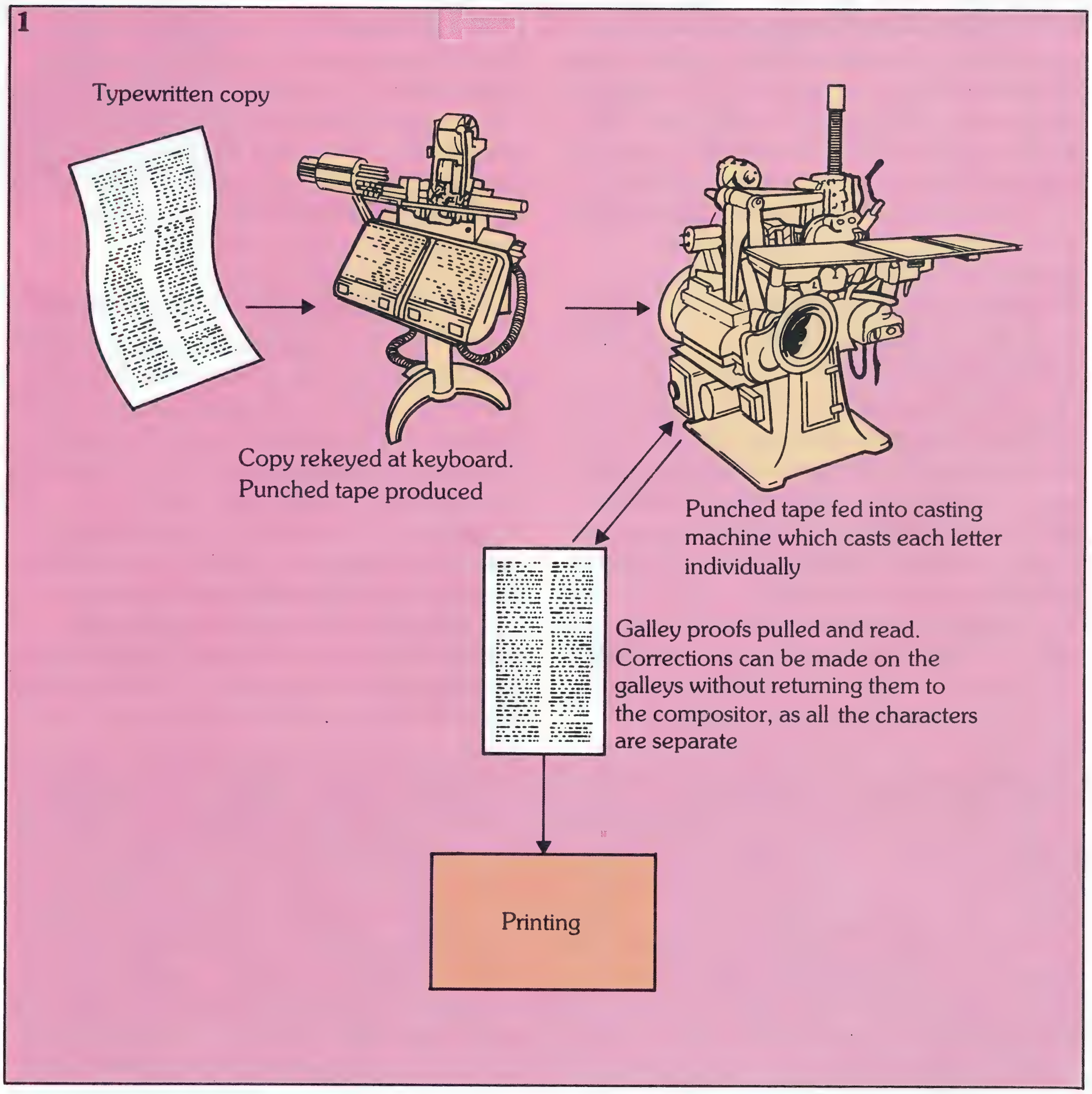
In some cases, word processing systems support an automatic spelling checker. These programs compare each word in the text with the contents of a large internal dictionary. When new words are typed in, the word processor flags the word and asks the operator 'is this a new word or a misspelling?' If the word is misspelt, the operator corrects the word; if the word is new, then it is added to the dictionary.

Most spelling checkers of this sort operate on a word-by-word basis and have no grammatical capability. For example, if the word *read* is transcribed for *red*, the automatic spelling check will be unable to judge that it is out of context and will not flag the error. However, true proof-readers are being developed and commercial systems should be available soon.

Some advanced text processors incorporate additional author aids. Bell Laboratories in the U.S., for example, has developed a system for simplifying convoluted prose.

Although most word processors are connected to printers, it is, of course, simpler and quicker for an editor to read and change text on the screen rather than on printed copy.

It is now possible to connect together word processors, desk-top computers and mainframe machines over a local area network. Thus, the word processor becomes a terminal capable of quite comprehensive filing and processing procedures – it can now make use of central data and software files at the centre of the electronic publishing system. Once this central database has been created it can be easily updated, amended and redefined. For example, *The Computer Users' Yearbook* is a large statistical directory of computer users, published by the Dutch company, VNU. Together with its associated software and micro directories, it is produced using a fully computerised database.



1. Monotype composing casts a character at a time from a matrix of metal characters.

Typesetting
The second stage in the electronic publishing process is typesetting. In order to gain an appreciation of what the new technology can do for publishing, we'll first take a quick look at conventional typesetting methods. How then, is the journalist's typewritten story converted to text on the printed page?

Remember that the writer may have retyped the story many times. The sub-editor then corrects the text, or copy, for house-style, grammar etc., and possibly retypes it. The copy must also be 'marked up' for typeface, size and format. Once this is done, the copy is ready for typesetting.

There are two main kinds of '**hot metal**' typesetting machine: **Monotype** and **Linotype**. Monotype was primarily used in book publishing. Here, the compositor takes the typed copy and *rekeys* it into a composing machine producing a punched paper tape as output. This paper tape is then fed into the typesetting, or casting, machine where, according to the pattern on the tape, single characters are cast and dropped, one at a time, from a matrix of metal characters onto a metal tray or galley. This tray of characters is then inked up and a paper print or 'galley' is taken from it. These galleys are then proof-read – corrections being made a character at a time by the typesetter.

Once corrected, these trays of metal type can either be arranged into pages, to be used as the printing plate in letterpress printing, or the printed galleys can be photographed to make a metal plate for more modern litho printing.

Linotype composing simplifies the

process a little and it is still used in newspaper production today. Instead of producing a character at a time ('mono'), the Linotype machine produces a line, or slug, of type ('lino') at a time without the need for paper tape. However, the journalist's copy is again *rekeyed*.

Monotype and Linotype processes are summarised in *figures 1* and *2* respectively. You can see now why the term 'hot metal' is applied to this kind of composition – literally because 'hot metal', usually lead, is used.

Photocomposition

The most important innovation in this field in recent years has been the advent of **photocomposition** or '**cold**' composition. (The term 'cold' is used to distinguish it from hot setting methods.) Although considerably speeding up the typesetting process, copy still has to be *rekeyed* by the typesetter, as shown in *figure 3*. Short codes are inserted into the copy specifying typeface, size, copy width etc.

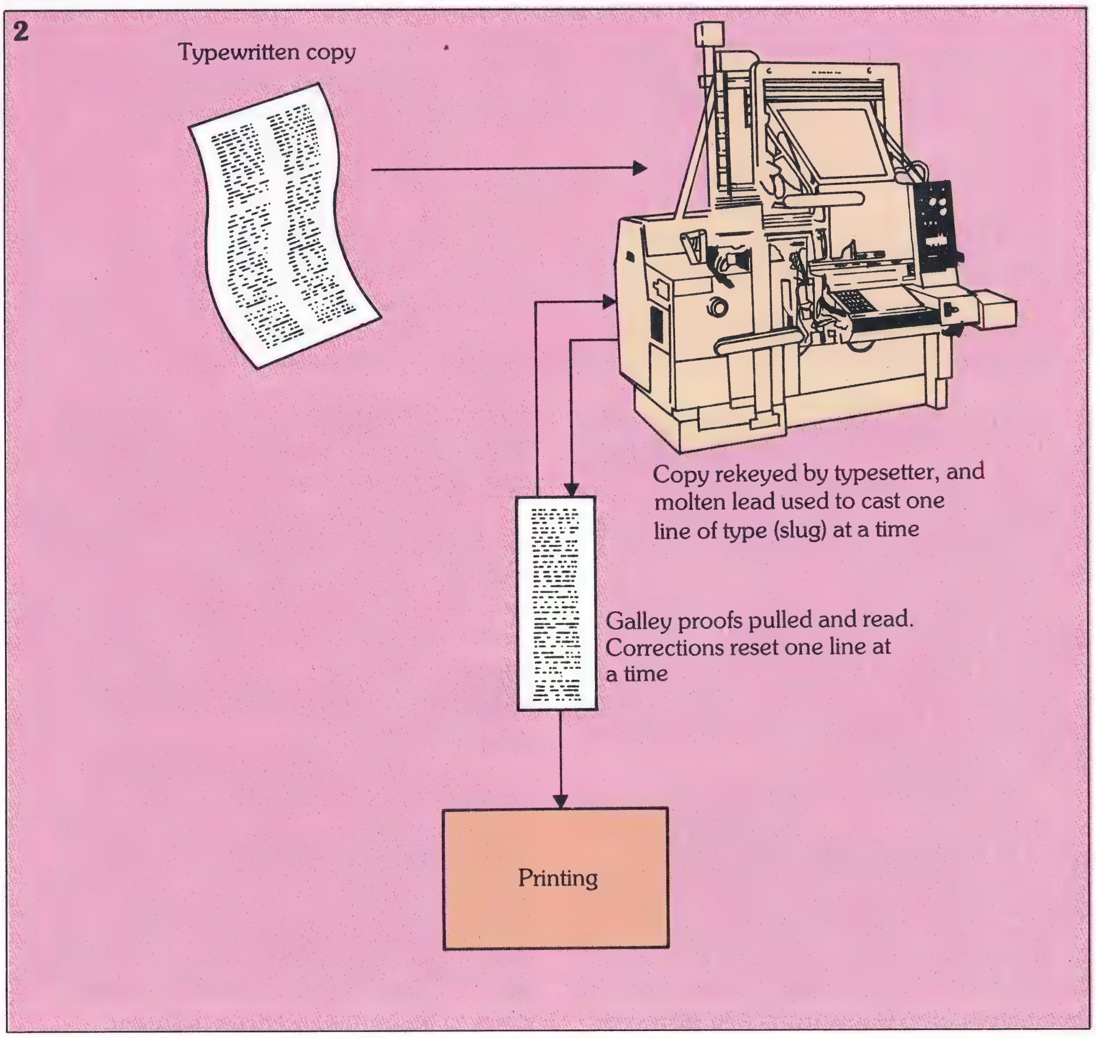
As we have said, the main advantage of photocomposition is, of course, speed. Operator's can achieve throughput rates many times faster than 'hot metal' typesetters and correcting copy is also considerably easier. Working conditions have also vastly improved – the new machines are quicker, cleaner and easier to use.

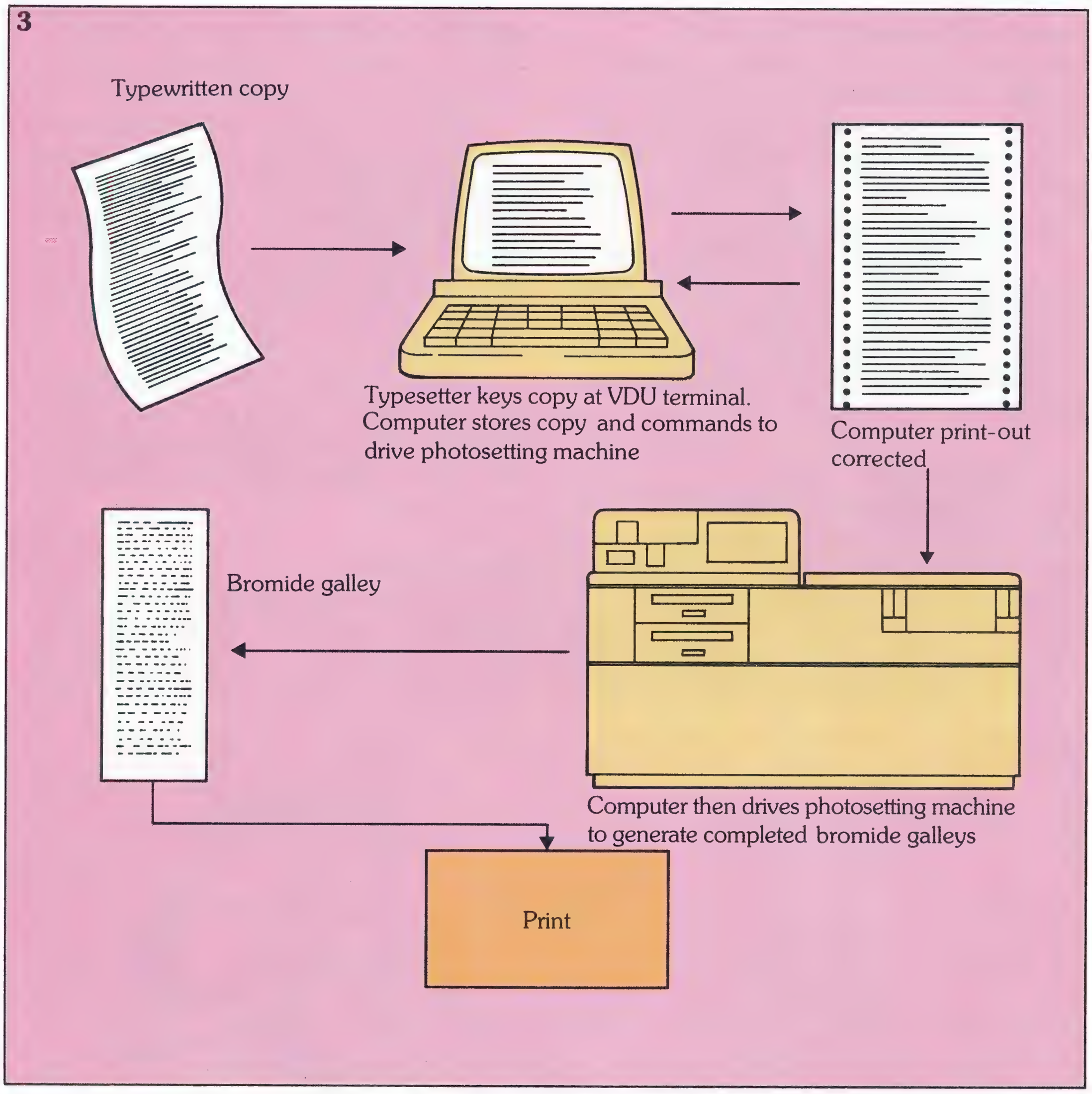
Having said this, though, the copy is still rekeyed and it is the elimination of this repetitive, time wasting rekeying that lies at the heart of what 'electronic publishing' really means.

The next step

As soon as journalists begin to use word processors, the publishing chain begins to look rather different. Phototypesetters are very similar to word processors: both have

2. Linotype composition produces a slug of type from molten lead.





3. Photocomposition involves exposing light sensitive paper to a light source. No hot metal is used and so this is often referred to as cold composition.

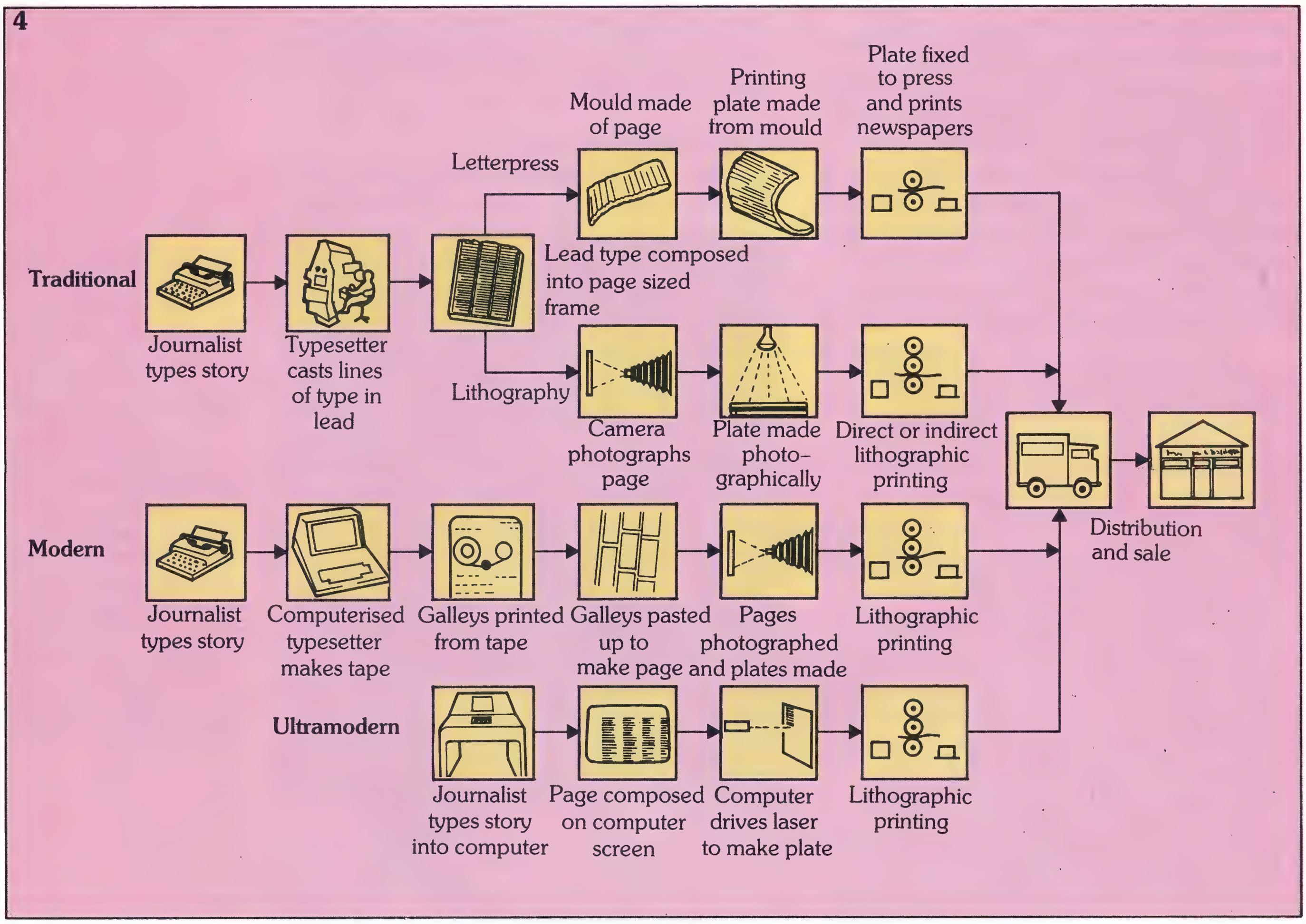
a conventional QWERTY keyboard; and both have a VDU and floppy disk storage. The only difference is that the word processor outputs printed text as hard copy, while the phototypesetter outputs a **bromide** or **film** (soft copy).

The logical next step is to send the disk output from the journalist's word processor direct to the typesetter. Here, the copy would only need the various typesetting commands added – *no further keying would be necessary*.

This has not been as easy as it sounds, though. One of the major problems to be overcome has been incompatibility of media. Thinking back to a previous *Basic Computer Science* article, you'll know that different manufacturer's format their disks in different ways, that is, the way that information is electronically stored on them is different. In practice, this means that one manufacturer's disk will not be able to be used in another's machine!

There are a number of ways in which this problem can be overcome. Where the journalist and typesetter use the same system, of course, either disks can be easily exchanged, or data can be transferred over a local area network. For example, a fully integrated system in a large newspaper or magazine office.

Secondly, some typesetters are equipped with a **multidisk reader** or **media converter**. This is a sophisticated kind of disk drive that can be programmed to emulate different word processors – it fools the typesetting machine into thinking that the word processor disk is compatible with it. Like the first method, it enables disks to be immediately exchanged.



4. The development of typesetting and printing methods showing the elimination of repetitive rekeying.
Source: 'Information Technology – An Introduction', Peter Zorkoczy, 1982.

However, these converters are extremely expensive, about £10,000. They can add about £35 to the cost of text transfer for each disk before typesetting even begins.

Optical character readers present another way around the problem. Providing a special OCR (optical character recognition) printwheel is used on the printer attached to the journalist's word processor, the copy can be scanned by the reader, which digitises the letters, converting them into ASCII coded characters which can then be displayed on the VDU of the typesetting machine.

There are also **text retrieval terminals** (TRTs), which for about £1,250 milk text from disk onto digital cassettes. These can then be given to a typesetter with a similar TRT.

Finally, and probably simplest of all, a modem link between journalist and typesetter means that the text can be transmitted over the telephone line. Modems can cost up to about £750, but hardware costs are falling all the time. Suitable modems should soon be available for a few hundred pounds.

A comparison of typesetting and printing methods is illustrated in *figure 4*.

The implications for authors and publishers

Once problems of compatibility have been dealt with, the implications for the publishing and printing industry become enormous.

To take first the newspaper or magazine journalist. The typed in copy has been checked, altered and reviewed on screen. The journalist then inserts the typesetting commands, and downloads the copy from word processor or microcomputer to phototypesetter.

Reporters on location need only pick up the nearest telephone to send in their copy, which has been typed into a portable microcomputer. If a modem was unavailable, the OCR output from a printer in a

local office could be sent via facsimile transmission and scanned by an OCR reader. Information can be gathered and processed much faster, and as hardware costs fall, much more cheaply.

The possibilities for the book publishing industry have been much discussed. It will be possible to produce books much more quickly than at present. This is particularly important in rapidly changing field such as science or politics.

As an example, take the proceedings of a scientific conference. Obviously, the sooner that this new material can be printed and sent to university libraries and research institutions the better.

Each speaker, using either a personal micro or a word processing system, amends his/her paper to conform to the publisher's house style. Disk output is then sent to the publisher where sub-editors check over the copy on screen. Perhaps, a heavily edited script is returned to the author, on disk, for approval.

Edited copy is then either downloaded via modem to the typesetter or sent on disk. The entire process taking only a few weeks.

Scientific journals could easily operate in this way and author's might send entire manuscripts on disk for direct input to the typesetter.

Obviously, these new methods will not magically halve typesetting costs and provide a new impetus for the publishing industry. However, once the problems of text transfer and encoding have been satisfactorily solved, typesetting costs can be dramatically reduced on a properly managed system.

Page design systems

So far, we have discussed the different ways in which copy can be input to a 'new technology' typesetting system. Once there, however, it must be incorporated with photographs and/or graphics and assembled into page layouts.

Again, more traditional methods of 'cutting and fitting' galleys, and pasting them onto layout sheets together with drawings and photographs is a labour intensive, repetitive task.

Sophisticated computer page make-up systems enable significant improvements to be made in the time taken to design and layout a magazine or book. Blocks of text can be moved around very easily and many different designs can be tried and discarded.

Today, a number of systems are available that can manipulate text and pictures on a screen. Some are attached to laser-based output devices or printers which mix black and white pictures on film along with type.

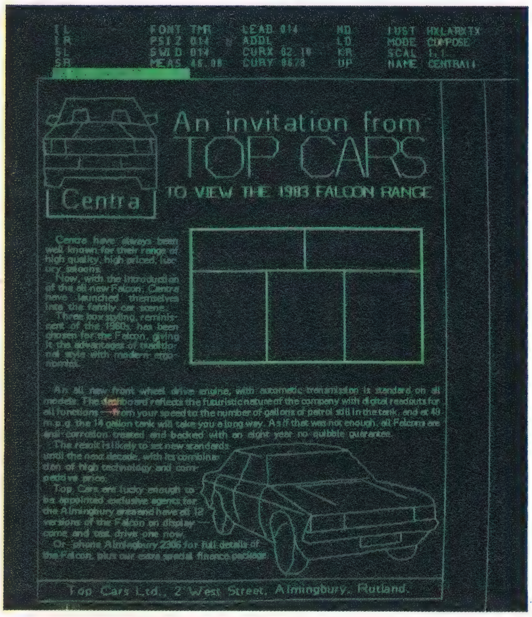
However, page make-up systems incorporating graphics have considerable restrictions. For example, compared with text, a great deal of processing power is required to manipulate a black and white image, let alone colour.

Pictures in newspapers and magazines are formed from a series of dots: the

5

5. Black and white photographs, or half-tones, are printed as a pattern of dots – the larger the dot size, the darker the area of the print.

larger the dot size, the darker that area of print (*figure* 5). The amount of information in a photograph, therefore, is considerable and a significant amount of memory is required to store it. This, of course, increases costs.



Right: an example screen layout possible with Linotype-Paul's Linoscreen Composer 2 system. To create this advertisement, the headline and body copy are first typed in – the headline can then be easily enlarged for greater impact. The outline of the car illustration is traced by a stylus onto a graphics tablet. Once in position, a box is drawn awaiting further copy and text is then 'flowed' around the illustration and box. (Photo: Linotype-Paul).

Micro-based systems

There have been a number of small publishing systems based on popular microcomputers. The greatest potential comes in the form of 16-bit machines: the IBM personal computer, the Sirius (ACT) and LSI Octopus are useful examples.

Micro software from Commercial Graphics has aroused considerable interest in the industry. The package, called CompMaster, is available on machines from Cifer, a British company, and it is being ported onto the IBM PC. Another British micro maker, LSI Computers, is expected to have it running on its Octopus by the autumn. The package is fairly inexpensive, costing around £5,000, and it includes 128 kbyte of memory and £1,000 of 'free' accounting software. While the system is said to be slow on the Cifer machine, it is still quite good value for money.

This particular device flows copy into defined areas and then shows the type as bars representing each line. Rules can also be drawn and illustration areas marked out using an electronic scalpel. The machine then has a complete page ready for printing.

Social aspects of computerised publishing

Contrary to the reservations expressed by sceptics, computer-aided print and production (CAP) has not yet made the skills of the professional printer redundant. CAP had adopted the established principles and conventions of the publishing industry, while bringing the techniques of print production within the grasp of even small companies.

For companies conscious of their image, professionally produced brochures and support materials are essential. While few organisations fail to appreciate the benefits of high quality sales literature, the cost of commercial printing is often considered too expensive. However, for all but the largest print runs, the cost of printing is small compared to the cost of typesetting. If that cost can be reduced using computer technology, the total outlay on print production can be reduced, thus providing increased custom for professional printing.

Unfortunately, single keying has led to considerable friction between management and unions as regards the origination of copy. Anxious to preserve jobs, the print unions at first resisted material that had been prepared on a word processor by their own office staff. Although some have now accepted in-house word processing, most still reject disks originated outside by authors or publishing company staff. Were publishing houses to introduce their own typesetting equipment, the industry would be transformed overnight.

Some publishers have already overcome this problem by producing what is known as **camera ready copy** for the printer. Individual authors provide suitable black copy, ready pasted down onto preprinted grids provided by the publisher. Spaces are left for illustrations which are supplied separately. The copy is printed out either by daisywheel printer or, in some cases, a typesetting machine.

It is known as camera ready copy because it goes to the printer 'ready for the camera'.

Undoubtedly some jobs will be lost, however others will be created as the typesetting industry becomes dispersed over many small companies and in-house production rooms.

Electronic news system

On January 17 1983, the British Broadcasting Corporation transmitted its first regular breakfast television programme, *Breakfast Time*. Never before had a daily programme been so long (2.5 hours), had so many sequences (an average of 75 each day), or been transmitted so early in the day (6.30-9.00 a.m.).

In June 1982, six months before the programme went on the air, the BBC recognised that there was no existing newsroom automated system available that met the demands of the new programme. As a result, the corporation decided to commission its own software.

The fibre optic technology that equips the BBC's **Electronic News System** (ENS) now electronically links journalists at their workstations to all other areas vital for a broadcasting news operation: computerised graphics, technical areas and production control rooms. ENS covers six floors, and has one kilometre of cable running from the central processor to its furthest terminal.

The ENS system uses two Hewlett-Packard 44 series minicomputers, one as a master CPU and the other as back-up; each has 3 Mbyte of memory. Either processor can be switched to support up to 44 Hewlett-Packard terminals with integral printers and six daisywheel printers. Two disk drives are associated with each machine storing over 500 Mbyte between them (*figure 6*).

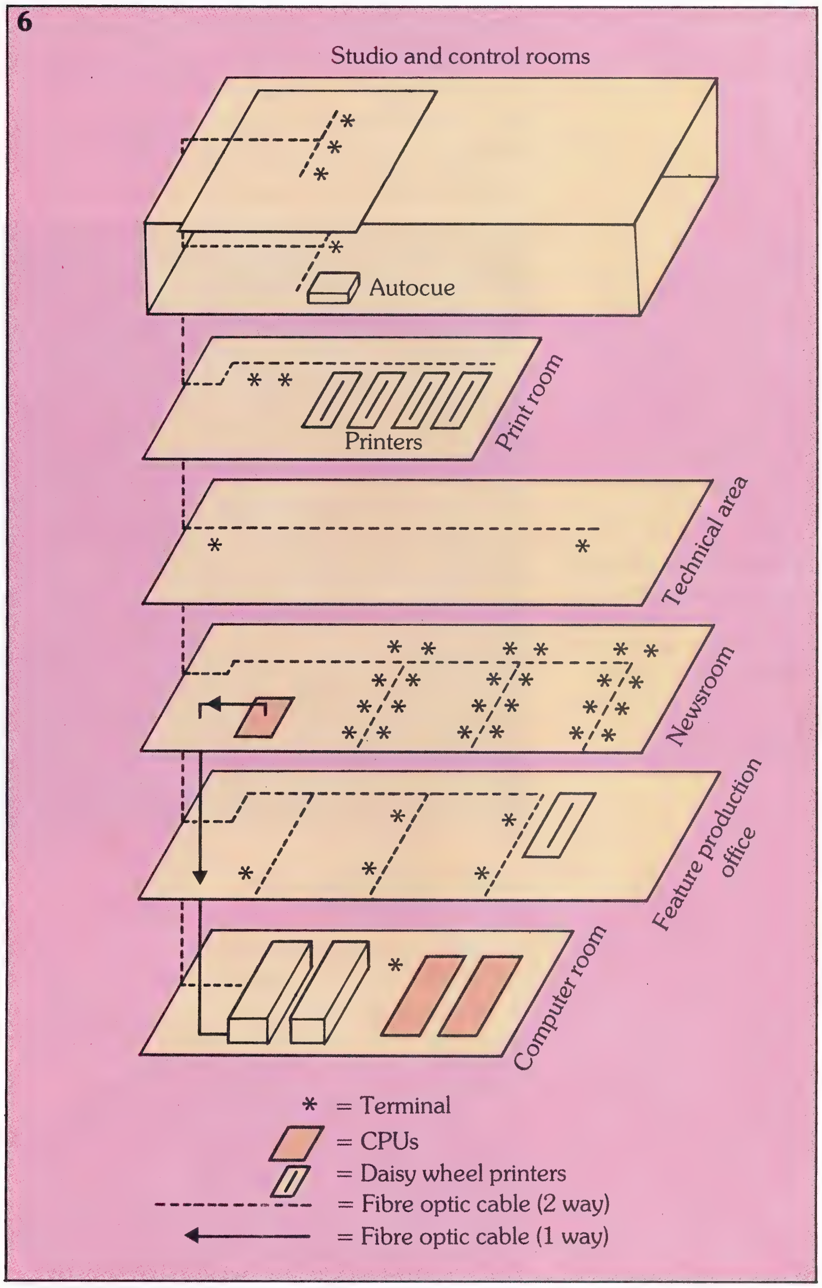
A separate microcomputer (72 kbyte) accepts information from outside news agencies and prints it simultaneously. These 12 agencies produce three million characters between them – this information has a lifespan of 24 hours in the system before it is overwritten by the next day's news.

A microcomputer with twin 5¼" floppies is located in the *Breakfast Time* studio itself, displaying running orders and scripts to the presenters.

ENS is primarily a broadcaster's tool, though any organisation using scripts could benefit from the system. Three facilities, COPY, SHELF and DIARY, were written into the host program by journalist programmers – these facilities file most of the show's raw data.

In addition to the minute-by-minute news agency coverage, the daily events diary cross references and subdivides entries under 80 categories. The electronic shelf stores scripts that are ready for transmission.

With the successful introduction of the system into the BBC, plans are well in hand to market the system worldwide. Systemsolve (Computer Services) who developed the software has demonstrated the system in America and is working closely with many European TV networks.



6. The BBC's electronic news system links the studio with the newsroom, production control and the computer room for graphics via optical fibre.

Electronic news gathering

Independent Television News (ITN) were the pioneers of electronic news gathering (ENG) in the U.K. Now, for outside broadcasts, all that is needed is a two man technical crew: a cameraman and a sound recordist.

With electronic cameras and portable editing equipment, signals can be fed through landlines or via satellites, providing pictures and news from almost any part of the world instantly. Film does not need to be processed, nor are news teams dependent on airline schedules (*figure* 7).

In 1982, the U.K.'s second independent T.V. channel, Channel Four, began news transmission using one of only two computerised newsroom services (the other is used by Cable News Network in Atlanta, U.S.A.). The **Newsfury** system was developed by Basys, a small Californian company, which ITN announced it was buying earlier this year. All four ITN bulletins should be coming from newsrooms using computers by the end of 1984.

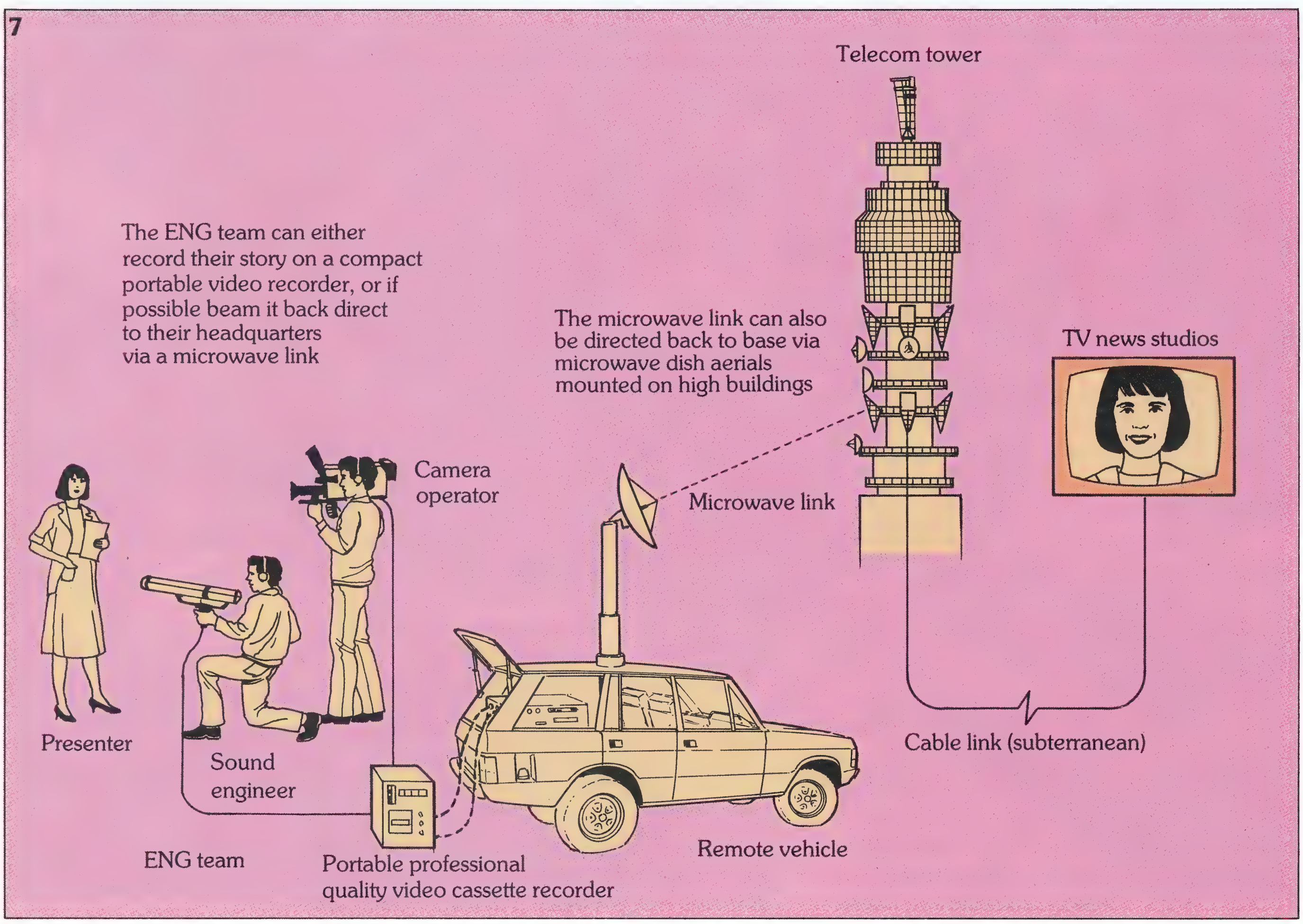
The most ambitious plan of all, now under consideration by the ITN board, is for a 24 hour world news and current affairs channel to be transmitted by direct broadcast satellite. This would be similar to the BBC's World Service on radio.

News agencies

Although publishing editorial systems have been electronically transformed over recent years, the **newswire** service still relies largely on technology introduced more than 30 years ago. The wire service comprises news agencies such as Associated Press, Reuters and United Press International (UPI). These agencies disseminate news in the form of text and photographs all over the world using telex and teleprinter equipment – hence the name wire service.

The problem of electronically incor-

7. How the new electronic news gathering equipment operates in the field.



porating photographs with text has assumed considerable importance since publishers have seen the advantages to be gained from integrating all elements of a page for direct input to film or printing plate. Much research has been carried out into the digital transmission and digital processing of newspaper pictures over the past few years. A number of commercial systems have been developed, including one from Muirhead Data Communications which electronically stores and processes continuous tone pictures and graphs into a form ready for integration into a full page layout.

The first production model of the Muirhead Electronic News Desk was installed by Deutsche Presse-Agentur (DPA) at their Frankfurt picture headquarters in 1983. It accepts pictures from a local scanner or on-line from a wire service and stores them on disk. The pictures are then able to be viewed on a monitor.

Once on the monitor, the editor is able to alter tonal areas for enhancement, zoom in on a particular area for enlargement, crop and even rotate the photograph for captioning. These functions are carried out in real-time via operator interaction with the keyboard.

DPA normally processes about 80 pictures a day. This includes archive shots for papers running special features, as well as pictures covering major news events which cannot be anticipated. About 40% of DPA's picture file comprises international pictures from UPI's network and so the captions need translating into about four different languages. This can also be carried out at the keyboard. At present, captions are manually typed and pasted onto the photograph for scanning.

The electronic news desk will become the centre for the agency's wire service photo's. The unit is composed of a powerful central processor, and a VDU or picture monitor. Large amounts of memory are needed for graphic images, and so the main form of storage in the Muirhead picture desk is optical disk storage.

There are 10 input/output channels on the desk which are essentially analogue-to-digital and digital-to-analogue converters operated by independent microprocessors. Photos are received conventionally in analogue form and are fed directly into the system, where the picture is digitised.

Above: Muirhead's Electronic Picture Desk. The conventional VDU and keyboard, on the left, control the system, while pictures are viewed on the monitor (right). (Photo: Muirhead).

When a picture enters the photographic desk it is given a priority rating by the editor. Should a picture needing quick transmission in order to meet copy deadlines come through, it is given a high priority for output over other pictures. This does not slow down any of the other operations performed by the desk.

This innovation is expected to improve the agency's service in a number of ways. Newspapers will be able to receive pictures from the agency much sooner because, although data transmission rates remain the same, picture processing is speeded up at the agency. This also makes the service more economical.

A second advantage is that when a photograph comes through the wire today, it has to be fully processed before it can be evaluated. This can take six or seven minutes and can be fairly costly in terms of photographic materials. Also, in the case of agencies, the picture is then usually cropped and most likely re-shot before it can be retransmitted, resulting in a loss of quality.

The final stage in the development of this electronic news desk is for it to be linked with the rest of the page composition system. About half of DPA's German customers use electronic page composition systems. The technology is also available for fully integrated typesetting, however, this has not yet been put into operation.

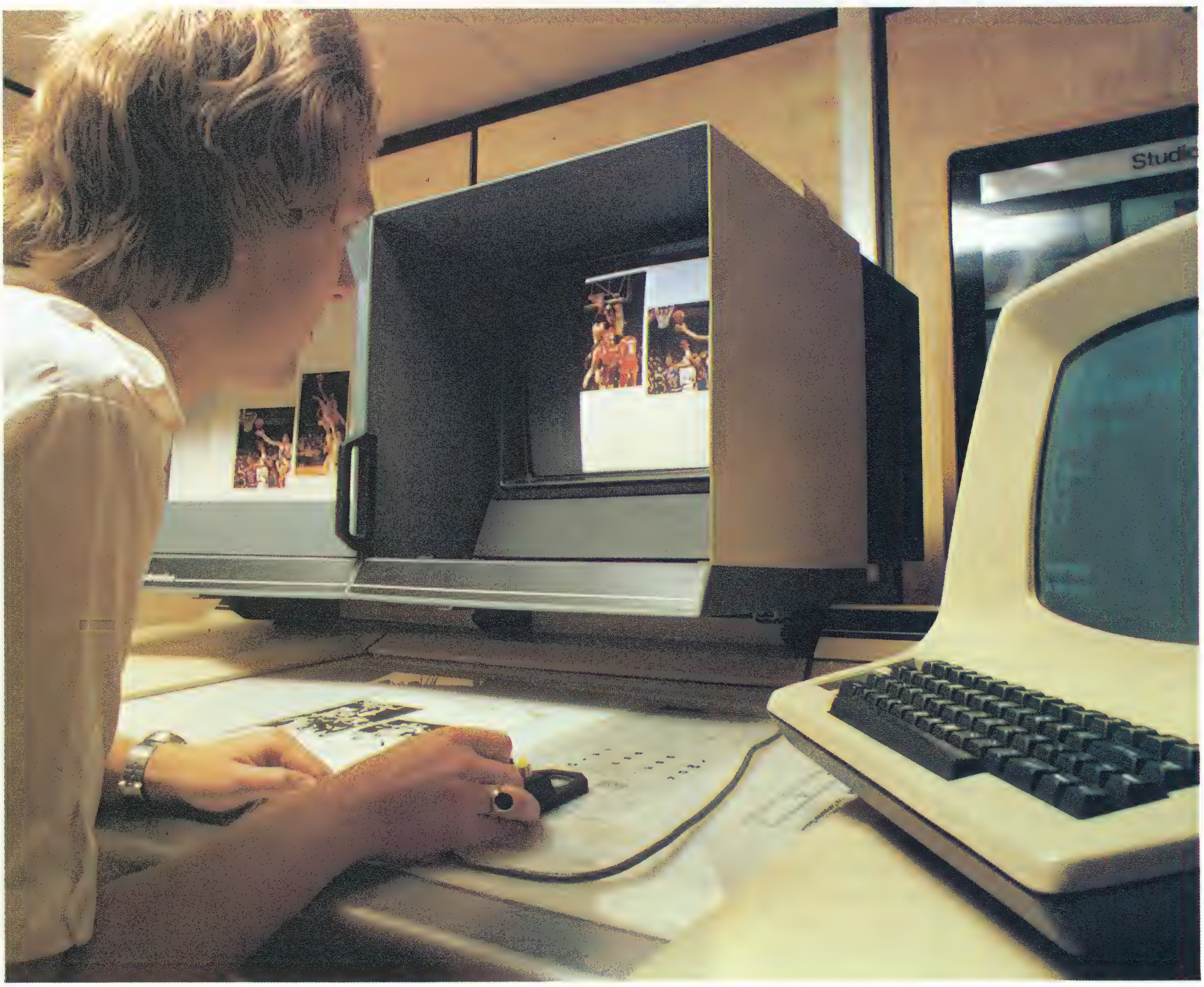
Possibilities for the future

The publishing and printing industries are primarily involved in the dissemination of information. As this product 'information' is becoming increasingly valuable, considerable research effort is being directed into methods which will enable it to be moved around as quickly and as cost effectively as possible – this will affect all forms of printed paper publishing and news gathering.

Already, information services provided by videotex and teletext are slowly replacing printed directories; electronic mail can 'post' information around the world without the need for paper; publishers are already acknowledging the advantages of storing their 'books' as microfiche, and therefore not needing large amounts of costly warehouse space; and facsimile transmission enables at least one newspaper to be simultaneously printed in London, Paris, Zurich and Hong Kong without duplicating the cost of typesetting.

The rising costs of paper and printing ink and the increasing complexity of modern printing machinery will probably motivate some replacement of centrally produced publications by electronically stored, displayed and distributed information in the near future.

However, electronic publishing is constrained by factors of ownership and accessibility – problems which have yet to be solved. We are still a long way from reading a novel on the TV screen.



Below: input to this interactive image editing system is via a large format digitising table; the stored images are then displayed on a 1024 × 1024 pixel colour monitor. Using the keyboard, an operator can modify both colour and position. An array processor is incorporated allowing image rotation and retouching. (Photo: Crosfield Electronics).

ELECTRICAL TECHNOLOGY

Analogue filters

Our study of Fourier analysis has shown us that analogue signals, such as audio and video signals, may be considered as combinations of a number of sine waves of different frequencies and amplitudes. For speech, most of these frequency components lie in the band from about 30 Hz to 4 kHz (although higher frequencies do exist, this is sufficient for satisfactory reproduction). The range for good quality music is from about 30 Hz to 20 kHz, and for television pictures, the band extends from 0 to 6 MHz. This range of frequencies for each type of signal is known as its **signal bandwidth**.

Usually when signals are transmitted only a limited **transmission medium bandwidth** is available. To make the most efficient use of this limited bandwidth, undesired frequency components outside each signal bandwidth must be removed. This can be achieved by using a network to act like a filter, which allows the required frequency components to pass through, but impedes the passage of all others.

There are many such **wave filters** which are categorised by the range of frequencies which they either **pass** or **stop**. These bands of frequencies are known as the wave filter's **pass band** and **stop band** respectively.

A filter which passes all frequencies from zero up to some value f_o, known as the cut-off frequency, and stops all those above this value is known as a **low pass filter**. The transmission characteristic of an *ideal* low pass filter (in black) and a practical form of it (in red) are shown in *figure 1a*. Here, the vertical axis indicates the transmission voltage ratio in decibels (0 dB corresponds to perfect transmission, and negative values refer to attenuation). The gain in the pass band is ideally 0 dB and in the stop band it is $-\infty$. The practical filter approximates to this.

A **high pass filter**, on the other hand, attenuates all frequencies *below* the cut-off frequency, f_o, and passes all frequencies *above* that value. Its characteristic is shown in *figure 1b*.

The characteristic given in *figure 1c* is that of a **band pass filter**. This graph shows that the filter passes all frequency components between some low cut-off frequency, f_1, and some high cut-off frequency, f_2. It also attenuates all frequencies less than f_1 and greater than f_2.

A fourth type of filter, the **band stop**, or **band reject filter** stops the transmission of all frequencies between f_1 and f_2, and passes all frequencies lower than f_1 and greater than f_2 (*figure 1d*).

Low pass filter

The simplest form of low pass filter is shown in *figure 2a*; the filter consists of the single capacitor C_1. The two resistors act as terminations; resistor R_1 enables a current to be developed as input to the filter; and the output voltage v_o is developed across resistor R_2. The filter transfer function, T(f), varies with frequency and its magnitude is given by:

$$|T(f)| = \frac{|v_o|}{|v_i|}$$

which is usually plotted in decibels as:

$$\log_{10}|T(f)|$$

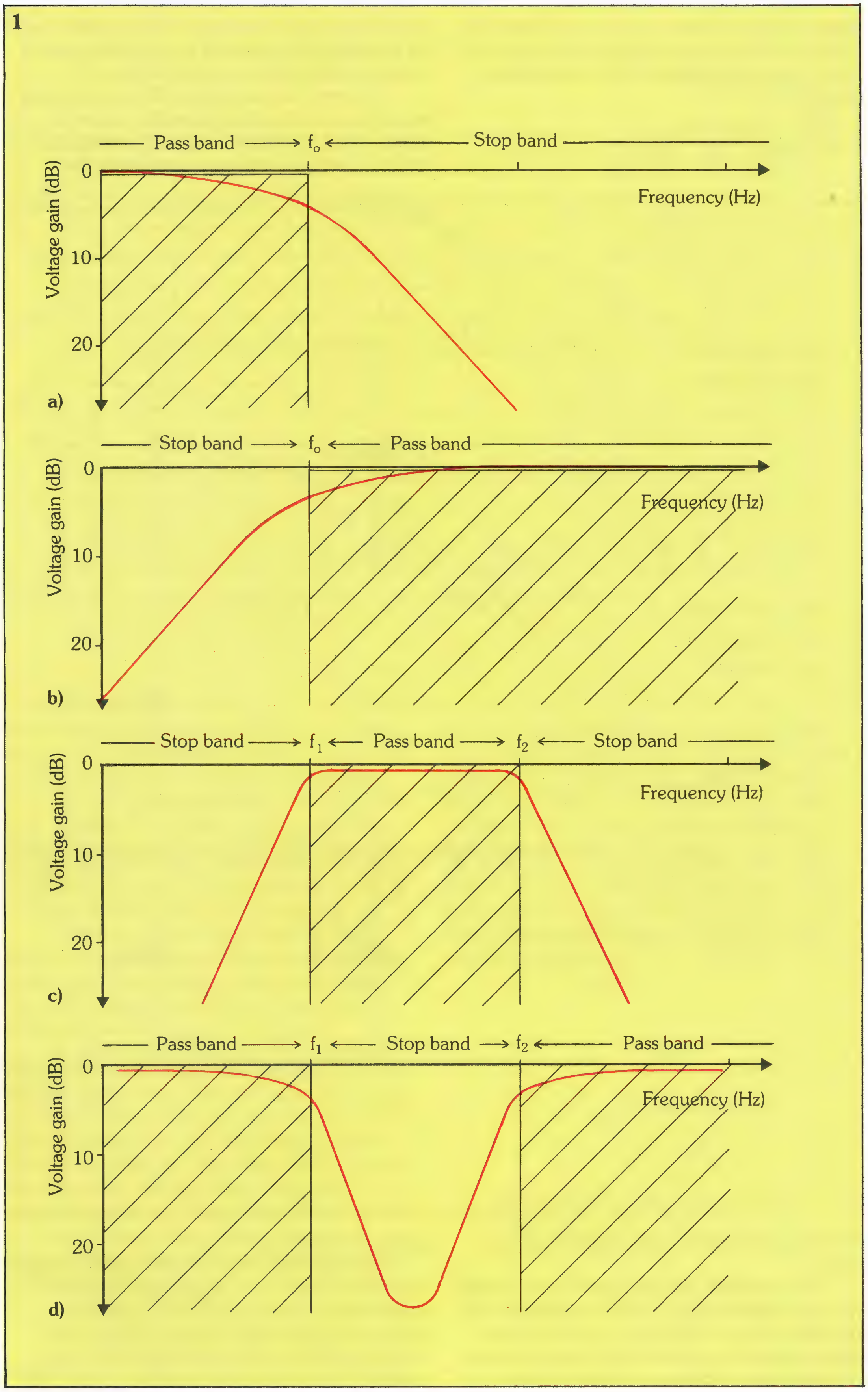
Looking at the filter of *figure 2a*, we can see that, at very low frequencies, the impedance of the capacitor is very high, acting almost like an open circuit. The voltage transfer ratio will therefore be given by:

$$\frac{v_o}{v_i} = \frac{R_2}{R_1 + R_2}$$

At very high frequencies, the capacitor acts almost like a short circuit and so the output voltage falls towards zero. The transfer charac-

Below: a scanning electron microscope being used to examine an integrated circuit.

Neville Miles



1. Transmission characteristics of various filters: (a) low pass; **(b)** high pass; **(c)** band pass; **(d)** band stop or band reject.

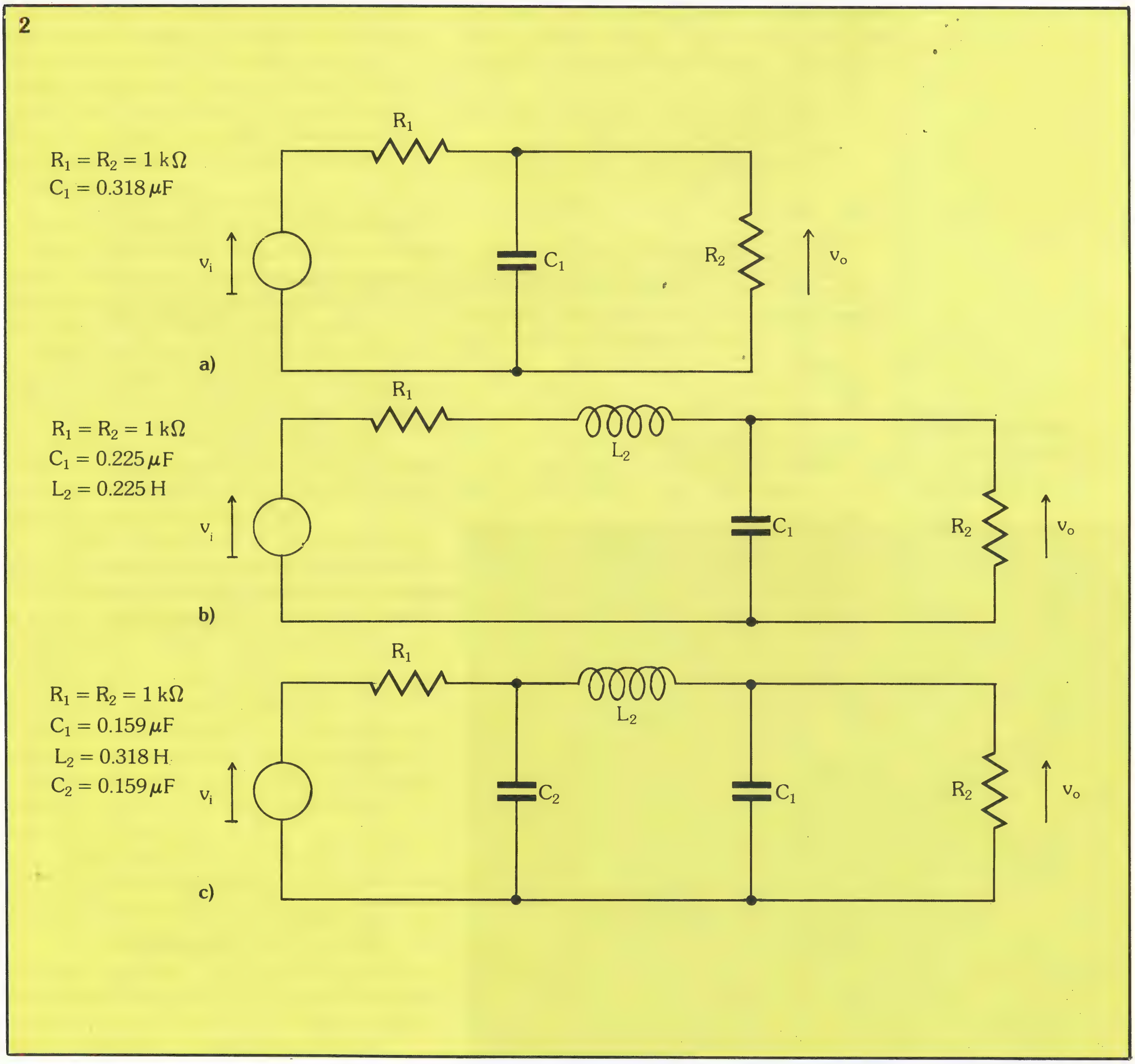
teristic, which is shown as curve A in *figure 3*, is similar to the red curve in *figure 1a* except that at low frequencies there is a finite attenuation given by:

$$20 \log_{10}\left(\frac{R_2 + R_1}{R_2}\right) \text{dB}$$

above the cut-off frequency. The response can be considerably improved by including a series inductor in the filter, as shown in *figure 2b*.

At very low frequencies, the inductor acts as a short circuit and the capacitor acts as an open circuit, so the low frequency voltage gain is (for $R_1 = R_2$) exactly the same as for the

2. (a) The simplest form of low pass filter comprises a single capacitor; **(b)** a second order filter; **(c)** a third order filter network.



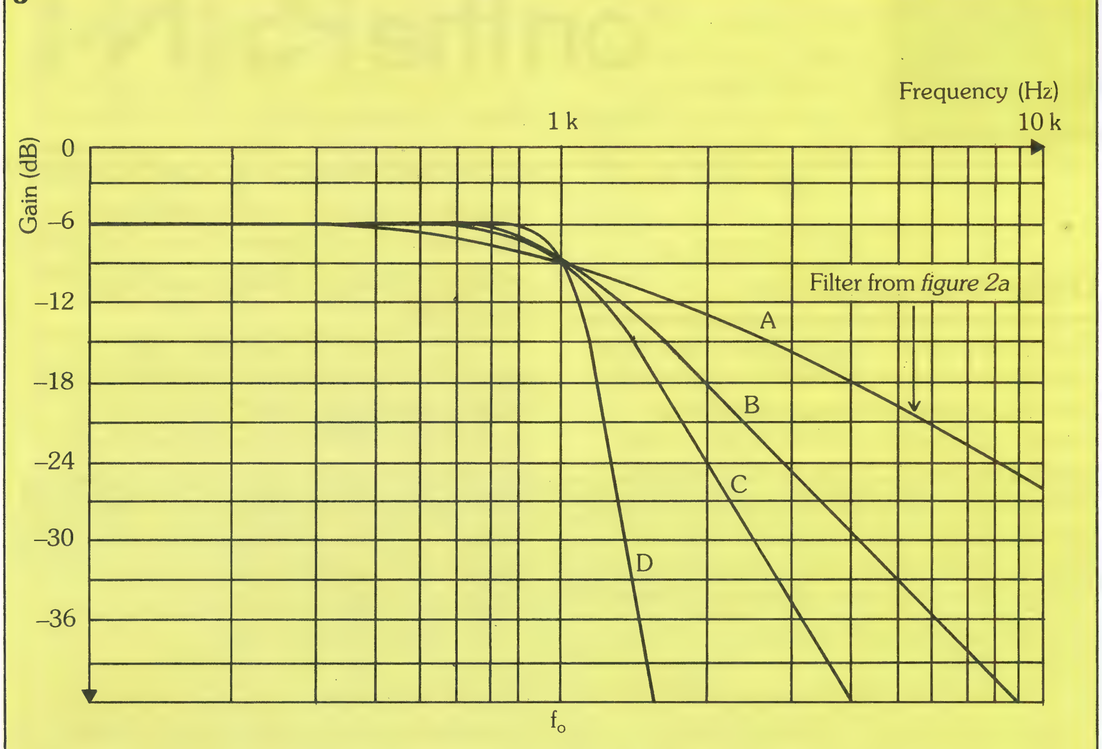
(N.B. the attenuation is the reciprocal of the gain.)

The example we have considered, where the cut-off frequency is 1 kHz and resistor R_1 is the same value as resistor R_2, is a rather poor approximation to the ideal filter response since the attenuation increases only very slowly

previous example.

At high frequencies, the impedance of the inductor becomes very large and that of the capacitor becomes very small. The output voltage therefore tends to zero as a result of these *two* different effects and also falls more quickly. This is shown in curve B of *figure 3* for

3



3. Transfer characteristics of various low pass filter networks.

some typical values of capacitor C_1 and inductor L_2. This filter network has two elements and is therefore known as a **second order filter**.

By adding a second capacitor, and thereby increasing the number of filter elements (inductive or capacitive components) to three, we derive a **third order filter**. This is illustrated in *figure 2c*; its characteristic (curve C of *figure 3*) shows an even faster fall in voltage gain.

This process of adding filter elements may be continued almost indefinitely: an 11th order filter, for example, containing 6 capacitors and 5 inductors exhibits the frequency response shown by curve D in *figure 3*.

At high frequencies, curve A of *figure 3* (for the first order filter) falls with a slope of 20 dB per decade while curve B falls at 40 dB per decade. This can be generalised for an *nth* order filter which, at high frequencies, falls at 20*n* dB per decade. We can see that the higher the order of the filter, the more closely it approximates the ideal low pass filter. However, a very close approximation to the ideal requires a large number of components which is both expensive and bulky. In the following *Basic Theory Refresher* we will see how some of these difficulties may be overcome.

The arrangement of inductors and capacitors shown in *figure 2* are not the only ones to realise a given specification of low pass filter. An alternative network could start from a series inductor at the output, with capacitors and series inductors back towards the input. Both these arrangements are known as **ladder networks**, because of their appearance. It is also possible to make **lattice filters** where the inductors and capacitors are arranged similarly to the lattice attenuator which was discussed in the previous *Basic Theory Refresher*. Other filter types also exist. □

12 COMMUNICATIONS

Data transmission on the PSTN-1

Data transmission

The transmission of digital data over wires was not, of course, invented to cope with the data transmission requirements of modern computers and microprocessor based equipment. Telegraph messages, remember, are digitally transmitted in the form of Morse code. The telex is also a form of digital telegraphic communication, using a 5-bit code for the transmission of 57 or so different characters or control codes.

The existing telephone system, on the other hand (sometimes known as the **public switched telephone network**, or PSTN), has been continuously developed as a totally analogue communications system, specifically for speech transmissions. It is therefore a higher grade communications system than either the telegraph or telex system, because the demands of transmitted speech signals are greater than those of telegraph or telex signals.

Accordingly, when high speed data transmission was required between computers and other digital devices, the PSTN provided the only available communications network that could cope. As we shall see, though, there is a limit to the amount of data which can be transmitted over telephone lines.

The fundamental principle of communications is that information is transmitted through some medium, from sender to receiver. The method of transmission, depending, to a large extent, on the medium available.

Computer communications information comprises patterns of bits representing logic states. A transmission medium such as wire may represent these bits as combinations of only two analogue voltages, typically 5 V (representing a bit of logic 1) and 0 V (logic 0). So, although digital states are inferred, it is the *analogue* voltages present in the wire which are transmitted.

As only two voltages are used, a pattern of bits can thus be thought of as a square wave type signal. Viewed on an oscilloscope, the displayed wave might look something like that shown in *figure 1*. From the analogue voltage levels present, we can see that the digital information represented by this wave is, in fact, a collection of bits, in sequence:

1 0 1 1 0 1 1 1 0 0 1 0

Fourier analysis

From previous considerations of Fourier analysis, we know that square waves (and, indeed, most types of waves) may be considered as a collection of sine and cosine waves. A true square wave, for example, with a frequency of, say, f Hz, comprises sine waves of frequencies:

f, 3f, 5f, 7f, 9f, 11f . . .

up to infinity. The amplitudes and phases of each wave differ in relation to the fundamental frequency, f Hz. For a square wave transmitted as a combination of analogue voltages (say, 5 V and 0 V) along analogue wires, there is also a DC component.

So, we can see that a true square wave (and any digital signal for that matter) must have an actual bandwidth of 0 Hz to infinity. This means that to transmit such a digital signal from sender to receiver and obtain perfect reception, the transmission medium must also have a bandwidth of 0 Hz to infinity. Of course, this is not possible – no such medium exists.

All transmission media have a limited bandwidth; the PSTN, for example, has a frequency range of about 300 Hz to 3400 Hz, i.e. a bandwidth of about 3100 Hz. The number of sine waves and cosine waves (making up the digital signal) which may be transmitted from sender to receiver

is determined by this bandwidth. If, say, the first six components of the Fourier series of a square wave were within the frequency range of the medium, then a recognisable (though deteriorated) square wave may be received. However, if only five, four, three, or two of the components are transmitted, then the received square wave becomes increasingly deteriorated, until finally it carries no information at all.

Obviously, then, the bandwidth of a transmission medium defines the amount of information which may be transmitted through it. But how is this amount calculated? And how is full utilisation of the bandwidth ensured?

Capacity

A **channel**, remember, is a one-way communications link between sender and receiver – a two-way telephone conversation between two users of the PSTN therefore takes place with the use of two channels.

Because the bandwidth of the channel depends on the bandwidth of the transmission medium, it therefore determines the maximum amount of information that can be transmitted. This, in turn, is related to the **capacity** of the channel, that is, the number of distinct symbols which may be received in a second.

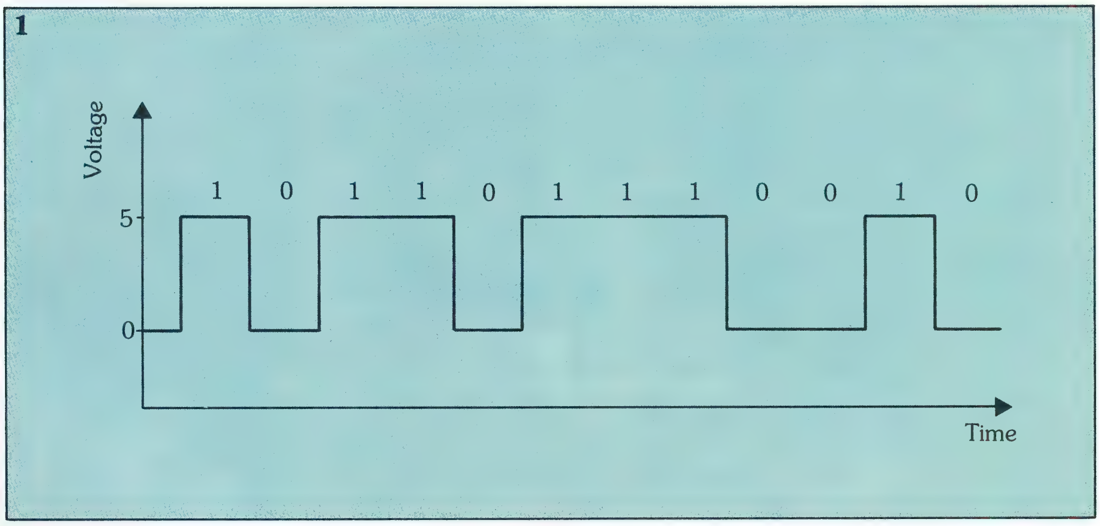
Channel capacity can be calculated from the **Shannon/Hartley law** formula:

$$C = W \log_2 (1 + \frac{S}{N})$$

where: C is the channel capacity; W is the channel bandwidth; and S/N is the channel signal-to-noise ratio.

For a typical telephone channel, with a frequency response of 300 Hz to 3400 Hz (i.e. a bandwidth of 3100 Hz), and a signal-to-noise ratio of 20 dB (i.e. 100), the channel capacity can therefore be found:

$$\begin{aligned} C &= 3100 \log_2 (1 + 100) \\ &= 3100 \left(\frac{\log_{10}(101)}{\log_{10}(2)}\right) \\ &= \frac{3100 \times 2.00432}{0.30103} \\ &= 20{,}640 \text{ bits s}^{-1} \end{aligned}$$



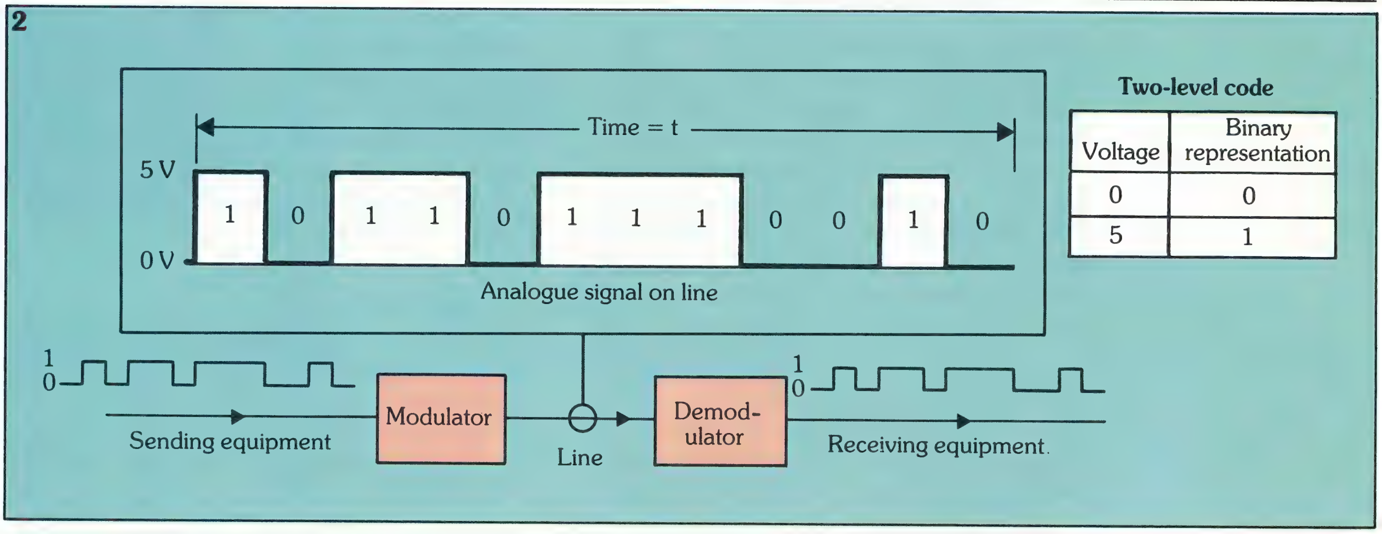
1. Digital data can be transmitted over the PSTN as a pattern of bits represented by 2 voltage states, say 0 V and 5 V. This signal might appear as a square wave on an oscilloscope.

This figure, however, is higher than that possible in practice for a number of reasons. First, the channel bandwidth is only an average value and may, at any given moment, be lower than 3100 Hz; similarly, the 20 dB signal-to-noise ratio is also an average value. Second, the equipment sending and receiving the information may not be capable of fully utilising the maximum possible capacity. Finally, not every frequency in the bandwidth of a telephone channel is free to be used for data transmission – some frequencies are used in the PSTN for signalling.

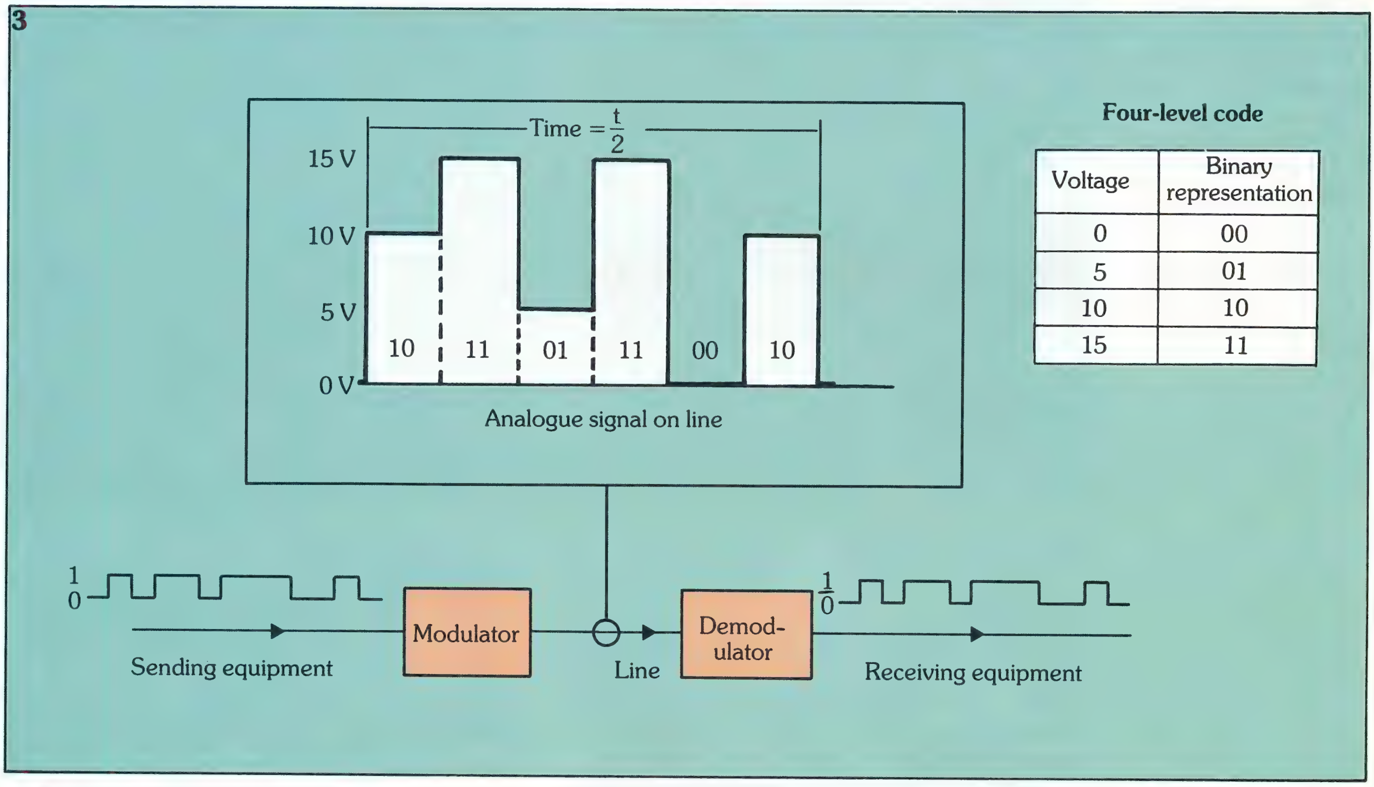
The overall effect of these problems is that a telephone channel is capable of transmitting much less information than it might seem.

Coding of data

Data to be transmitted (in bits of 1 or 0 logic states) is encoded by a **modulator**



2. Digital data is encoded by a modulator into a two-level analogue signal, then decoded by a demodulator at the receiver.



3. A four-level analogue code uses four voltage levels to represent four different dibits.

into a two-level analogue signal, and decoded at the other end of the line by a **demodulator** back into data, as shown in *figure 2*.

The number of bits received as data by the receiving equipment is known as the **data signalling rate**. If, for example, a bit is received every 2 ms, then 500 bits are received each second. The channel is therefore said to have a data signalling rate of 500 bits s^{-1}.

Another way of considering the amount of information received is to look at the **modulation rate**, i.e. the number of modulated signal elements received by the receiving equipment. In the two-level code example, the modulation rate has the same value as the data signalling rate, i.e. 500 modulated signal elements per second. The unit of modulation rate is the **baud** and so the modulation rate of this two-level code example is 500 baud.

Although the data signalling and modulation rates are numerically identical in this example of a two-level code, they are different with other codes.

An example of the use of a four-level code is shown in *figure 3*. Four voltage levels (0 V, 5 V, 10 V and 15 V) are now used to represent four different combinations of two bits. (Combinations of two bits are often called **dibits**.) A modulator is now used to produce the four signalling element voltage levels. If, say, a modulated signal element is received every 2 ms, then the modulation rate is, as before, 500 baud.

The data signalling rate for the four-level code, however, is different because each signal element contains two bits. Each bit is therefore received in an average time of only 1 ms and so the data signalling rate is 1000 bits s^{-1}.

Similarly, *figure 4* shows an eight-level code used to convey the same information. Eight voltage levels (0 V, 5 V, 10 V, 15 V, 20 V, 25 V, 30 V and 35 V) are now used to represent eight different combinations of *three* bits. The modulator now produces the eight, voltage level signal elements from each group of three bits to be transmitted, and the demodulator produces the received bits from each received signal element.

As before, the modulation rate is 500 baud, but the data signalling rate is 1500 bits s^{-1}, because a bit is received, on average, every 0.66 ms.

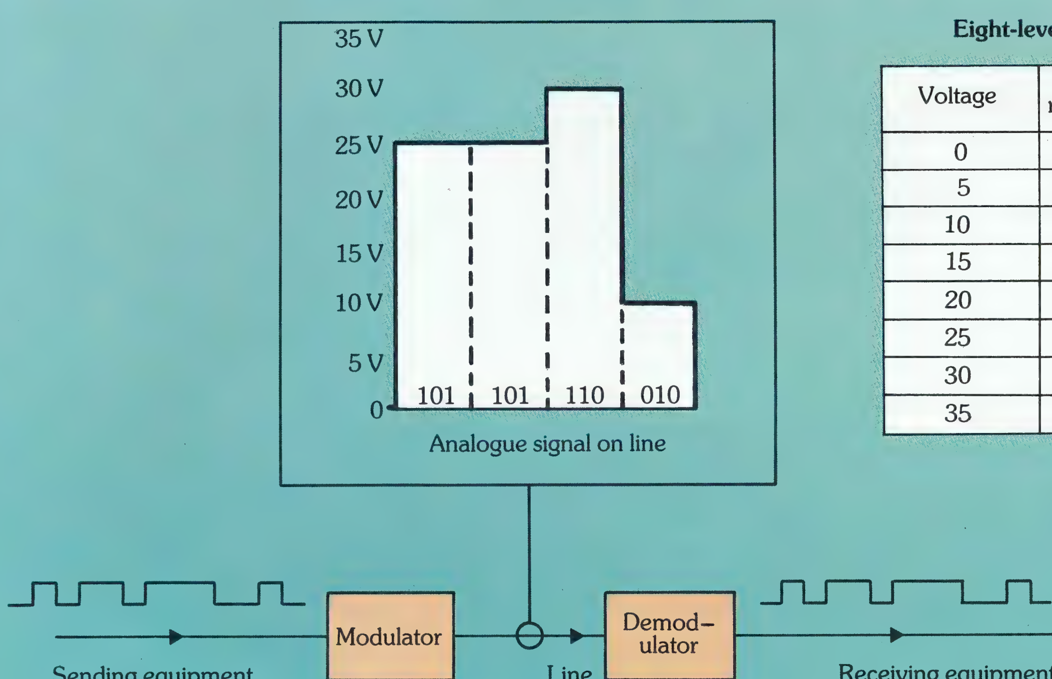
Data signalling and modulation rates are commonly mistaken for the same thing – but as we have just seen, they are entirely different. The modulation rate is mainly used by communications engineers to compare the information handling capabilities of lines; the data signalling rate is used by computer engineers to define data input and output to data equipment.

Right: British Telecom's Merlin M1100 system. This terminal can be used as part of a word processing system when networked to Telecom Gold (an electronic mail system) and can also access Prestel.

The Research House/British Telecom

4. An eight-level code represents eight different combinations of three bits.

4



Eight-level code

Voltage	Binary representation
0	000
5	001
10	010
15	011
20	100
25	101
30	110
35	111

Encoding digital signals

In *figures 2, 3* and *4* we saw that two pieces of equipment are required to interface the sender and receiver of digital information onto the line: the modulator, which encodes the information into an analogue signal for transmission; and a demodulator, which decodes the analogue signal back into digital information.

There are three methods of information transfer between equipment. Unfortunately, these definitions are not universally accepted. For instance, CCITT definitions:
1) **simplex** – where transmission is possible in two directions, but only allowed one way at a time;
2) **half duplex** – where two-way simultaneous transmission is possible, but sending and receiving equipment only allows transmission in one direction at a time;
3) **duplex** – where simultaneous two-way transmission is possible;
differ from those definitions accepted in North America (and in the computer industry):
1) simplex – where only one-way transmission is possible and transmission in the other direction is *not* possible;
2) half duplex – where two-way transmission is possible, but not simultaneously;
3) full duplex – where two-way simultaneous transmission is possible.

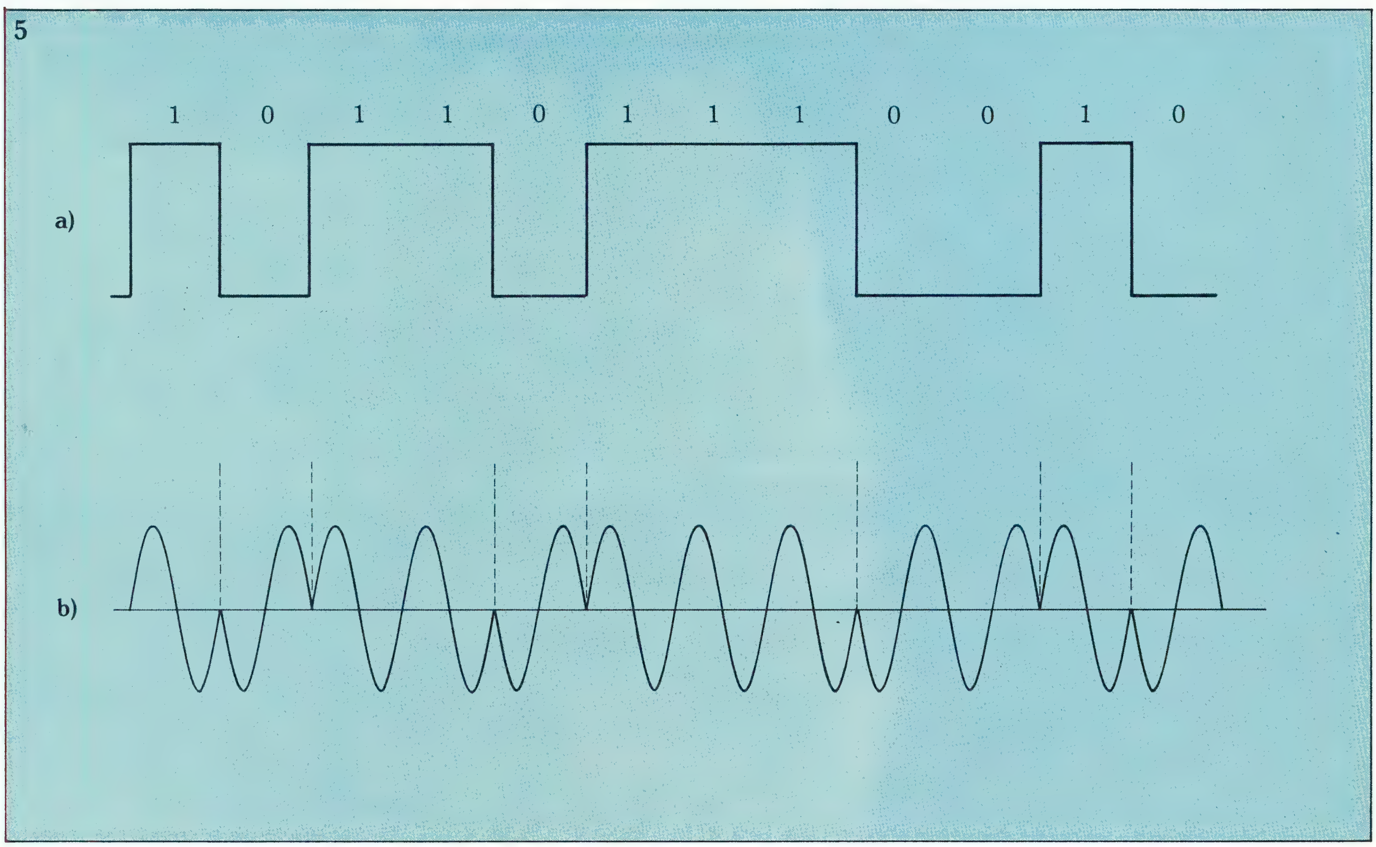
Inevitably, these differences cause confusion, so whenever a term is stated the defining body should also be stated. Whichever definitions are stated, however, the methods still relate to information transfer regardless of transmission media, whether it be wire, coaxial cable, radio, satellite, optical fibre etc. – as long as one or more channels exist.

Modems

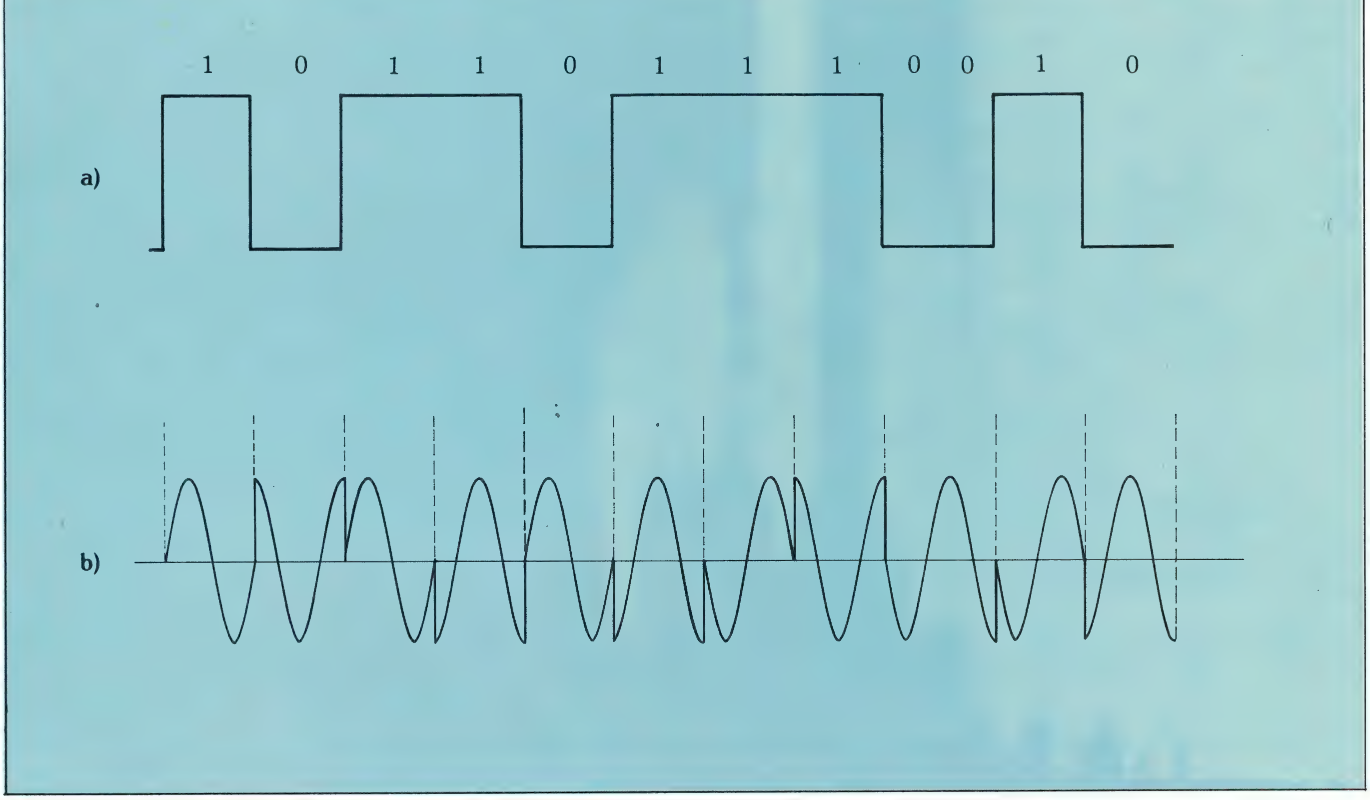
Most data communications links (not all) are two-way, i.e. two channels are required in the link – one to transmit information from a first piece of equipment to a second, and one to transmit information from the second to the first.

In such two-way links via the PSTN, each piece of data equipment obviously requires a modulator and a demodulator. These are generally combined together into a **modem** (**mo**dulator/**dem**odulator). The modem type depends largely on the

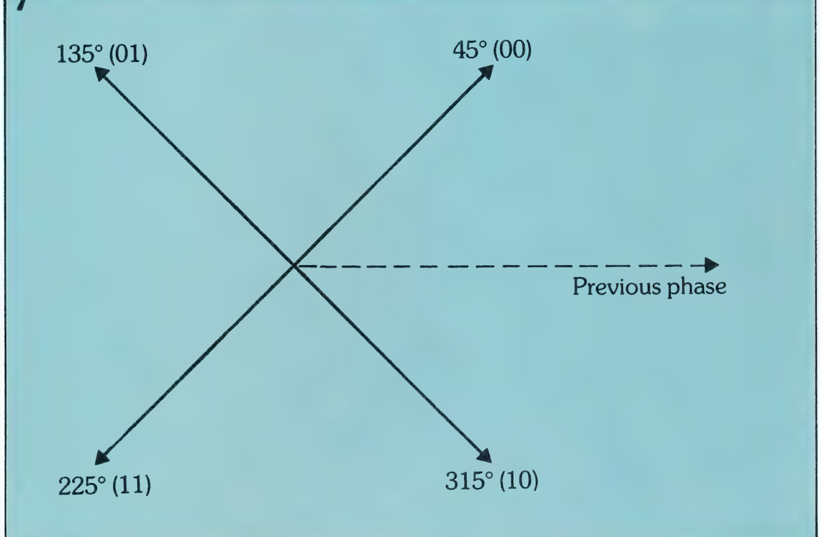
5. (a) A sample digital message signal; (b) the resulting phase shift keyed signal after phase modulation onto an analogue signal.



6



7



6. Differential phase modulation: (a) message signal; **(b)** after differential two-phase modulation.

7. Phase diagram showing the phase changes produced by differential four-phase modulation.

type of channels used, i.e. how great the bandwidth is, and how high the signal-to-noise ratio is etc., and also on the required data signalling rate.

Any analogue signal, and the analogue signals created and decoded by modems are no exception, can vary in one or more of three characteristics – amplitude, frequency and phase. Correspondingly, three main methods may be used by modems to modulate digital information onto analogue lines: amplitude modulation; frequency modulation; and phase modulation. A fourth method uses a combination of two or these.

Amplitude modulation

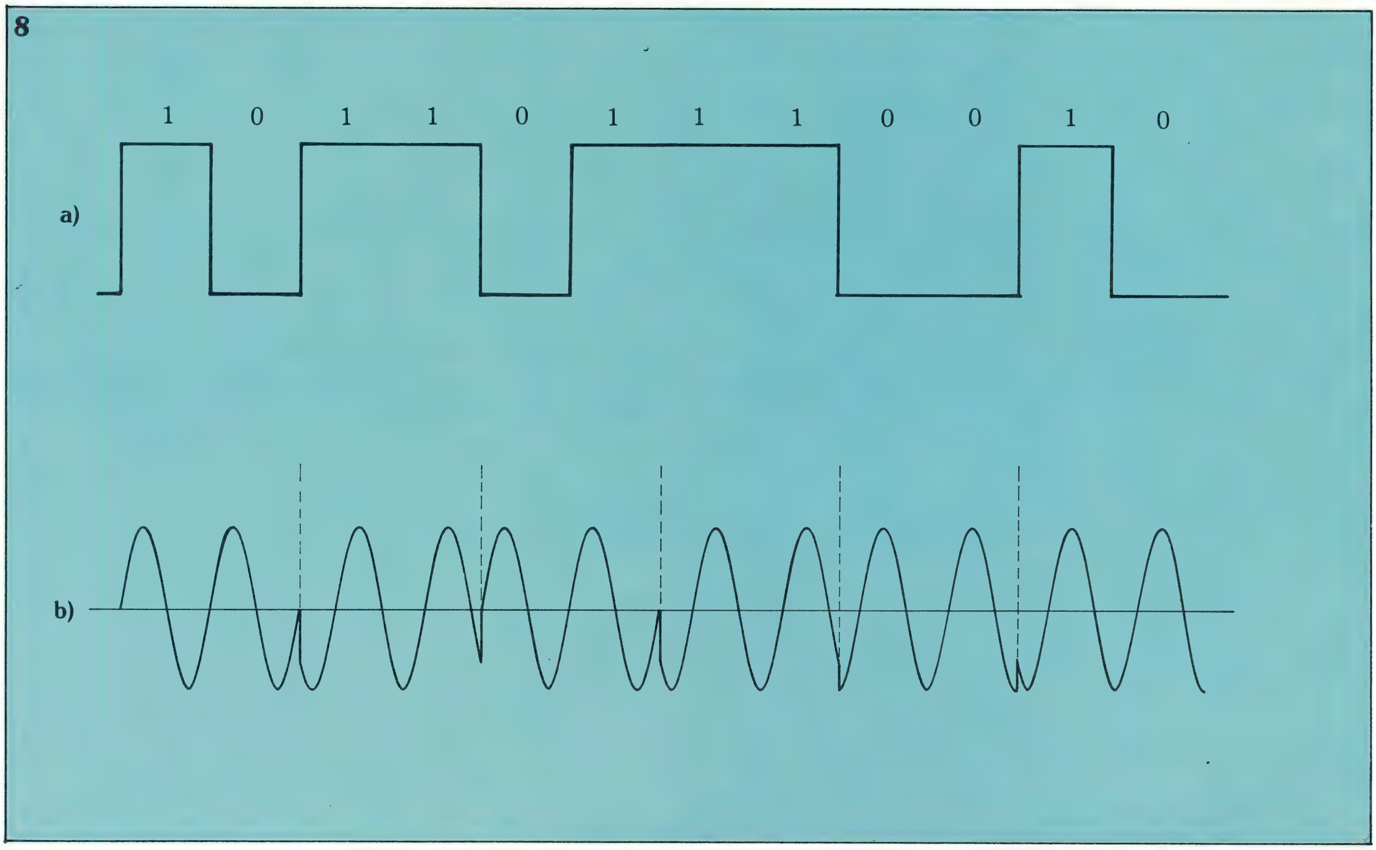
Amplitude modulation techniques in telephone systems (see *Communications 3*) comprise continuously varying carrier amplitudes, directly related to the analogue speech signals. Carrier amplitudes in a *digital* amplitude modulation system however, are stepped, according to the applied digital signal.

Frequency modulation

In a similar way, frequency modulation of digital signals, known as **frequency shift keying** (FSK), is used to produce a carrier signal with stepped frequencies.

Phase modulation

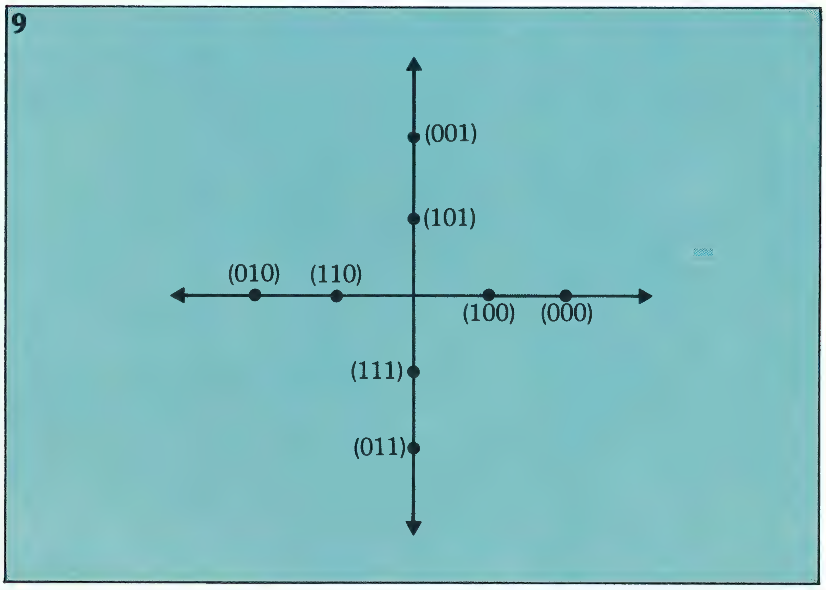
There are a number of ways phase modulation may be used in modems to transmit information over analogue lines. *Figure 5a* shows the example digital message signal,



and *figure 5b* shows the resultant phase modulated signal, known as a **phase shift keyed** (PSK) signal.

A logic 1 level of the digital message signal causes an output carrier signal of a set phase to be produced by the modem. When a logic 0 is used to modulate the carrier signal, the signal is 180° out of phase with that for logic 1. One of the disadvantages of this simple type of phase modulation is that a reference carrier signal is essential in the receiving modem, to allow a comparison of phase when demodulating the received analogue signal back to a digital message signal.

A phase modulation technique in which a receiver carrier signal is not required (although sometimes used, anyway) is the **differential phase modulation** method. Here, each bit to be transmitted alters the phase of the carrier signal by an amount depending on which logic state it represented. For example, a 0 bit may be coded as a +90° phase change, whereas a 1 bit may be coded as a +270° (i.e. –90°) phase change. The message signal and resultant analogue signal of a modem operating on this principle are shown in *figures 6a* and *b*.

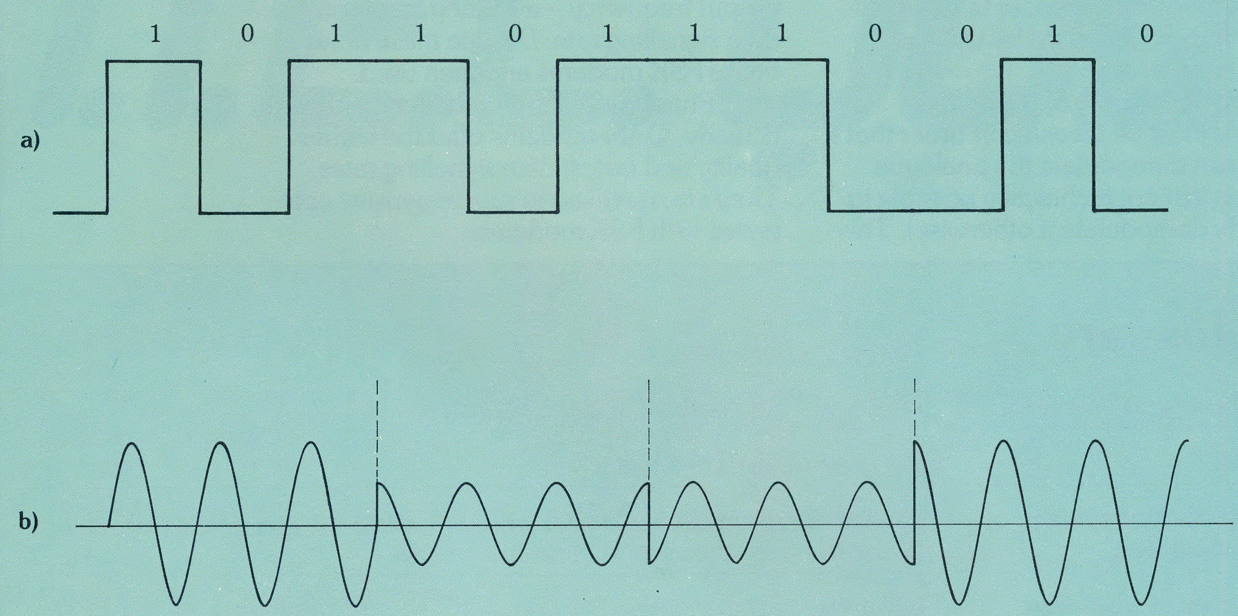


As only two phase changes are used to modulate the carrier, this method is defined as **differential two-phase modulation**. There is nothing to stop more phases being used to modulate the carrier signal, each phase representing, say, a combination of bits. For example, **differential four-phase modulation**, in which four

8. (a) Digital message signal; (b) signal after differential four-phase modulation.

9. Amplitude-phase diagram showing the carrier amplitudes and phase changes in quadratuure amplitude modulation.

10



10. (a) Digital message signal; (b) carrier analogue signal after quadrature amplitude modulation.

different dibits (i.e. combinations of two bits) modulate the carrier with four different phase changes.

A phase diagram illustrating the phase changes produced by the four dibits is shown in *figure 7*, and *figures 8a* and *b* show the example digital message signal, along with the resultant modulated carrier analogue signal.

Differential four-phase modulation is a form of four-level encoding of the analogue signal and so, of course, when used we must be aware that the modulation rate (in baud) is not of the same numerical value as the data signalling rate (in bits s^{-1}). There are, in fact, two bits per baud.

Quadrature amplitude modulation

The fourth method of modulation used in modems was said earlier to be a combination of two methods. **Quadrature amplitude modulation** (QAM) is a combination of amplitude modulation and phase modulation techniques and, indeed, is sometimes known as **amplitude-phase modulation**. It forms an eight-level encoded analogue signal, as each different group of three bits is represented by one of eight different combinations of carrier amplitude and phase.

A possible amplitude-phase diagram, illustrating the carrier amplitudes and phase changes produced by the eight combinations of bits, is shown in *figure 9*. The example digital message signal and resultant modulated carrier analogue signal are shown in *figures 10a* and *10b*.

Three bits are now represented by each baud of analogue signal.

Comparison of modems

In terms of quality, modems using the amplitude modulation method alone are not usable on the PSTN. The fact that received information depends totally on the amplitude of the received analogue signal means that any changes in analogue amplitude affect the information. PSTN channels do not, however, always maintain constant attenuation. This, plus the high levels of noise (particularly impulse noise) which occur on PSTN channels, results in a high rate of error.

Modems using the frequency modulation principle are common. There are

two main drawbacks to their use:
1) Many frequencies on the PSTN are allocated for other purposes (e.g. signalling) and therefore cannot be used as carrier frequencies.
2) At least half a cycle of the carrier frequency must be received in order that a modem can demodulate the analogue signal (it is just not technically possible to accurately demodulate it otherwise). This means that the digital message signal must not change faster than twice the lower output frequency – a limiting factor on the data signalling rate. Despite these drawbacks FSK modems are often used.

Phase modulation modems and, particularly, QAM modems offer the highest quality and fastest data signalling rates. They are, needless to say, expensive compared with FSK modems.

Glossary

data signalling rate	number of bits received as data. Measured in bits s^{-1}
dibit	a combination of two bits
differential phase modulation	modulation technique in which each signalling element modulates the phase of a carrier by a predetermined angle
duplex	two-way simultaneous transmission of information. A CCITT definition
frequency shift keying (FSK)	a modulation technique in which each bit of a digital message signal modulates a carrier frequency
full duplex	two-way simultaneous transmission of information. A North American/computer industry definition
half duplex	either: a transmission link where two-way simultaneous transmission of information is possible, but sending and receiving equipment only allows transmission in one direction at a time (CCITT); or, where two-way transmission is possible, but not simultaneously (North American/computer industry)
modem	a modulator/demodulator. Used to connect digital equipment to analogue lines, for the purpose of long distance data transfer
modulation rate	number of modulated signal elements received. Measured in baud
phase shift keying (PSK)	modulation technique in which each bit of a digital message signal modulates a carrier signal's phase
PSTN	public switched telephone network
quadrature amplitude modulation (QAM)	modulation technique which is a combination of amplitude modulation and phase modulation. Also known as amplitude-phase modulation
Shannon/Hartley law	formula used in defining transmission channel capacity in bits s^{-1}

TEST YOUR PROGRESS
with the

I.T.E.C. QUIZ

COMMUNICATIONS – 11

1. As a cellular radio user moves from cell to cell, the radio equipment has to be quickly retuned to a new frequency channel. This is carried out automatically.
True or False?

2. Densely populated areas will be divided into larger cells than sparsely populated areas.
True or False?

3. The cellular system was adopted so that:
a There could be a substantial increase in the number of mobile radio users
b The best use could be made of the available frequencies
c An improved radiophone service would be available
d All of these reasons

4. Cellular radio cells are drawn as hexagons because:
a This is the same shape as the areas of coverage
b Six channels are used
c They can be easily drawn in clusters
d None of these

5. The cellular radio system is linked to the PSTN via the network switch.
True or False?

6. How do base stations monitor calls in progress?
a Randomly
b Regularly but intermittently
c At five minute intervals
d Continuously

7. Careful planning and aerial siting ensures that communications between base and mobile are not interrupted by radio black spots.
True or False?

8. Cellular radio offers full duplex operation.
True or False?

Answers to last week's quiz

COMMUNICATIONS – 10
1 c
2 b
3 e
4 e
5 b
6 True
7 False

MICROPROCESSORS – 5
1 True
2 True
3 False
4 c
5 True

MICROPROCESSORS – 6
1 True
2 a
3 True
4 False
5 c
6 d

COMMUNICATIONS – 12

1. The capacity of a channel is:
a Half of its bandwidth (because there are two channels on an analogue telephone link)
b The maximum amount of information it can transmit
c Twice its bandwidth
d Not related to bandwidth
e b and d
f None of these

2. A modem is used for:
a Digital transmission of analogue information
b Analogue transmission of digital information
c Digital transmission of digital information
d Analogue transmission of analogue information
e All of these
f None of these

3. The number of bits received as data, by the receiving equipment of a digital communications link is:
a Known as the data signalling rate
b 20,640 bits s^{-1}
c Measured in bits s^{-1}
d Measured in baud
e a and c
f a and d
g b and c
h b and d

4. The channel capacity of a channel with a frequency response of 200 Hz to 4200 Hz, and a signal-to-noise ratio of 20 dB, is:
a 26,633 bits s^{-1}
b 266,330 bits s^{-1}
c 20,640 baud
d 8,000 Hz
e Impossible to calculate from the information given
f None of these

5. In a communications link using an eight-level code, the value of the modulation rate is three times the value of the data signalling rate.
True or False?

6. Frequency shift keying is a method of encoding digital information for transmission on analogue lines.
True or False?

7. In differential phase modulation, each signalling element to be transmitted:
a Alters the phase of the carrier signal from that of the previous element
b Is represented by a carrier
c Causes a change in carrier frequency
d Alters the carrier signal amplitude
e a and b
f a, b and c
g None of these

8. Quadrature amplitude modulation modem techniques use an eight-level coding system.
True or False?

COMING IN PART 43

Microprocessors 7 begins a discussion of possible **applications for SAM** (Simplified Architecture Microprocessor), a fictitious microprocessor.

Data protection – why is it necessary? How can it be achieved? Find out in *Computers & Society 12*.

Communications 13, the second of two articles on data transmission on the PSTN, takes a detailed look at the different types of **modems** and how they work.

PLUS: *Basic Theory Refresher* – looks at **active analogue filters**.